Results from the 1978-79 Tagging Experiments Involving Juvenile Pacific Cod *(Gadus macrocephalus)*

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October 1985

Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1843

86-1147/

Canadian Manuscript Report of Fisheries and Aquatic Sciences

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RESULTS FROM THE 1978-79 TAGGING EXPERIMENTS INVOLVING JUVENILE PACIFIC COD (*Gadus macrocephalus*)

by

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Cat. No. Fs 97-4/1843E ISSN 0706-6473

Correct citation for this publication:

Westrheim, S. J. 1985. Results from the 1978-79 tagging experiments involving juvenile Pacific cod (Gadus macrocephalus). Can. MS Rep. Fish. Aquat. Sci. 1843: 71 p.

ABSTRACT

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During January-March 1978-79, 3,380 trawl-caught Pacific cod (Gadus macrocephalus) were tagged and released; and 589 (17.4%) were subsequently recaptured. The purpose was to determine the feasibility of tagging juvenile cod for age validation and recruitment studies. Release areas were Georgia Strait (2,083/409/19.6%) and southwest coast of Vancouver Island (1,297/180/13.9%). Age composition of released cod was 11.0% age-1 ($\bar{L}$ ≈ 23-26 cm), 80.7% age-2 ($\bar{L}$ ≈ 44 cm), and 8.3% age > 2 (adults, >54 cm). Pre-release mortality rates varied inversely with age-class; varied directly with sea state; were increased, but usually not significantly, by overnight holding and double tagging. Recapture rates generally varied directly with age and sea state at release; were lower for double-tagged and "handicapped" (injury, gas, low viability, loose tag), and usually significantly lower for the latter. Double-tagging results were inconclusive with respect to shedding rate of anchor tags. Time at liberty was relatively short for all age-classes--maxima were 8-13 quarter-years. Eighty-three to ninety-three percent of the recaptures occurred during the tagging year. Dispersion of tagged cod was limited--83-94% were recaptured in their respective tagging areas. Age composition of emigrants was similar to that of non-emigrants, with one exception. Principal recapture areas for emigrant cod tagged in Georgia Strait were 4A (U.S.-Georgia Strait) and 3C-N (S.W. Vancouver Island), and for emigrant cod tagged off southwest Vancouver Island, Areas 4A and 4B, and the west coast of Washington State. Von Bertalanffy growth parameters based on growth increments of recaptured cod were: K=0.45 (Area 4B) and 0.49 (3C-N); L_∞ = 86 (4B) and 74 (3C-N) cm. It is concluded that juvenile cod can be tagged successfully, most likely at age 1+ during September.

RESUME

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De janvier à mars 1978 et 1979, on a étiqueté et remis à l'eau 3,380 morues du Pacifique (Gadus macrocephalus) capturées au chalut; par la suite, on a recapturé 589 individus (17.4%). L'expérience avait pour but de déterminer s'il était possible d'étiqueter de jeunes morues pour des études sur le recrutement et sur la valeur des techniques de détermination de l'âge. Les poissons ont été relâchés dans le détroit de Géorgie (2,083/409/19.6%) et près de la côte sud-ouest de l'île Vancouver (1,297/180/13.9%). La composition par âge des morues relâchées était la suivante: 11% d'âge 1 ($\bar{L}$ =23 à 26 cm), 80.7% d'âge 2 ($\bar{L}$ =44 cm) et 8.3% d'âge > 2 (adultes, >54 cm). Les taux de mortalité avant la remise à l'eau étaient inversement proportionnels à la classe d'âge; ont varié en fonction directe de l'état de la mer; ont augmenté, mais généralement de façon non significative, à la suite de la mise en bacs des poissons la nuit et d'un double étiquetage. De façon générale, les taux de recapture ont varié en fonction directe de l'âge et de l'état de la mer au moment de la remise à l'eau; étaient plus faibles pour les individus étiquetés deux fois et pour les individus "handicapés" (blessure, gaz, faible viabilité, étiquette mal fixé) et généralement beaucoup plus faibles pour le dernier groupe. Les résultats du double étiquetage se sont avérés peu concluants en ce qui concerne le taux de perte des étiquettes à ancrage. Le temps passé en liberté a été relativement court pour toutes les classes d'âge, les périodes maximales variant de 8 à 13 trimestres. De 83 à 93% des recaptures ont été enregistrées au cours de l'année d'étiquetage. La dispersion des morues étiquetées a été limitée: 83 à 94% d'entre elles ont été recapturées dans les secteurs où on les avait étiquetées. La composition par âge des émigrants était identique, à une exception près, à celle des poissons qui n'émigrent pas. Les principaux endroits de recapture pour les morues émigrantes étiquetées dans le détroit de Géorgie ont été les secteurs 4A (E.-U.; détroit de Géorgie) et 3C-N (S.-O. de l'île Vancouver); pour les morues émigrantes étiquetées au sud-ouest de l'île Vancouver, ce fut les secteurs 4A et 4B, de même que la côte ouest de l'Etat de Washington. Les paramètres de croissance de Von Bertalanffy basés sur les augmentations de croissance des morues recapturées étaient les suivantes: K=0.45 (Secteur 4B) et 0.49 (3C-N); L_∞ = 86 (4B) et 74 (3C-N) cm. On conclut qu'il est possible d'étiqueter avec succès de jeunes morues, le moment le plus propice étant en septembre lorsque les individus sont âgés de 1 + ans.

INTRODUCTION

Pacific cod (Gadus macrocephalus) is an important species in the groundfish fishery of British Columbia. Studies of its biology and distribution were reactivated in 1975, in anticipation of Canada's promulgation of the 200-mile economic zone. Two particularly vexing, and unsolved, problems encountered in past and present studies have been validation of age determination methods and description of the recruitment process.

Age determination methods employed and/or investigated include otoliths (Ketchen 1970), scales (Kennedy 1970; Westrheim and Shaw 1982), fin rays (Chilton and Beamish 1982, Westrheim and Shaw op. cit.), and length-frequency analysis (Foucher and Fournier 1982.) Otoliths were deemed unreadable (Ketchen op. cit.) and scales were demonstrated to be unreliable (Beamish et al. 1978; Westrheim and Shaw op. cit.). Fin-ray sections remain under investigation. The length-frequency method has not been validated. B. M. Leaman, of this Station, proposed that juvenile cod, of known age, might be tagged and inoculated with oxytetracycline (OTC) and the age structures of subsequent recaptures would provide an accuracy test for age determination. This proposal was considered plausible because juvenile cod are readily identified to age due to their rapid growth (Ketchen 1961; Beamish et al. 1976, 1978).

Cod recruit to the commercial fishery primarily over ages 2.0-3.2. Hence, cod tagged at any age prior to 2.0 could be used as a cohort to investigate recruitment.

Three tagging experiments were conducted during January-March 1978-79--two pilot experiments in the Strait of Georgia (Area 4B) and one at "production-scale" off west Vancouver Island (Area 3C-N[1]) (Fig. 1). Age validating aspects, with respect to scales, were reported elsewhere (Westrheim and Shaw 1982). This report deals with survival of tagged cod, time at liberty, distribution, and lineal growth.

MATERIALS AND METHODS

TAGGING

General details of tagging procedures were similar in each experiment. Nylon anchor tags were applied with a "gun" to anaesthetized (MS-222) cod. In the 1978 experiment, a second, suture, tag was applied to

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[1]Area 3C-N is the northern two-thirds of Area 3C which lies within the Canadian 200-mile economic zone established in 1977. Area 3C-S lies in the U.S. 200-mile economic zone, established the same year.

some cod to measure, if possible, the shedding rate of the anchor tags. Condition of each tagged cod was recorded at release. Further details on the individual experiments are available in Leaman et al. (1979) and Foucher et al. (1979, 1980). Some operational features differed between the present study and the earlier reports cited, viz., air-bladder deflation, method of release, and time of recording condition of the tagged fish.

Air-Bladder deflation. This procedure was employed successfully in 1978, with a hypodermic syringe. Similar efforts in 1979, in Area 4B, were generally unsuccessful, and cod with hyper-inflated air bladders were usually not tagged. For the Area 3C-N experiment, also in 1979, no attempt was made to deflate air bladders, and again cod with hyper-inflated air bladders were usually not tagged.

Release method. For the 1978 and 1979 experiments in Area 4B, tagged cod were tranferred by dipnet from the recovery tank to the sea--the charter vessel had a low freeboard. In the Area 3C-N experiment, in 1979, the recovery tank was hinged to the ship's rail, and all viable, tagged cod were released en masse by winching up the recovery tank until water and fish were spilled overboard. The charter vessel had a relatively high freeboard.

Condition at release. For the 1978 and 1979 experiments in Area 4B, condition of each tagged fish was noted at time of tagging and at time of release. For the 1979 experiment in Area 3C-N, condition of each fish was only noted at time of tagging. At time of release, dead, tagged cod were removed from the recovery tank, but no records were kept on condition of other individual cod.

RECAPTURE

A reward was paid for returning recaptured tagged cod and a "bonus" if the whole fish, with tag(s) intact, was returned. Most recaptures occurred in the processing plants. For those recaptures, every effort was made to determine which trawler landed the cod, and where the cod was caught.

ANALYSIS

Analyses were undertaken of the three experiments with special reference to age-class--1, 2, and >2. These analyses dealt with pre-release mortality, recapture rate, time at liberty, distribution, and growth. Secondary investigations considered recapture rate with respect to condition at release, overnight holding, and double-tagging--the latter two only applicable to the 1978 experiment.

rates were undertaken indirectly with the specialized Chi-square of a "2 x 2 table" (Dixon and Massey 1969, p. 242) as follows:

$$x^2 = \frac{(ad - bc)^2 n}{(a+b)(c+d)(a+c)(b+d)} \quad ; \text{degrees of freedom} = 1$$

where a = numbers dead (or recovered) in category A (age x)
b = numbers dead (or recovered) in category B (age y)
c = numbers not dead (or not recovered) in category A (age x)
d = numbers not dead (or not recovered) in category B (age y)
n = a + b + c + d
N.B. All values must be ≥ 5.

The relatively large numbers in all categories precluded the "continuity correction" recommended by Dixon and Massey (op cit.).

Growth analysis involved qualitative comparison of general results, and estimation of von Bertalanffy parameters (K and L_∞) using a modified form[1] of the Munro (1982) method. This simple method requires only a desk calculator, and seemed appropriate to the limited data available.

RESULTS

INVENTORY OF EXPERIMENTS

During January-March 1978-79, 3,380 Pacific cod were tagged and released, and 589 (17.4%) were subsequently recaptured (Table 1).

In the January-February 1978 (Area 4B) experiment, 974 tagged cod were released and 231 (23.7%) were recaptured (Table 1). Principal release location was Swanson Channel in Minor Statistical Area (MSA) 18 (Fig. 2)--959 released and 229 (23.9%) recaptured. Other localities were Yellow Rock (12/1/8.3%) and Cape Lazo (3/1/33.3%) in MSA 14.

In the January 1979 (Area 4B) experiment, 1,109 tagged cod were released and 178 (16.1%) recaptured (Table 1). Principal release location was Swanson Channel, in MSA 18 (974/161/16.6%) (Fig. 2). The only other location was Trincomali Channel (MSA 17)--135/17/12.6%.

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[1]Recaptures were grouped into quarter-year time periods and mean growth increments, by age-class.

In the February-March 1979 (Area 3C-N) experiment, 1,297 cod were tagged and released, and 180 (13.9%) were recaptured (Table 1). Three sub-experiments have been delineated--February and March on Amphitrite, Big and Clo-oose banks, respectively (Fig. 3). In February, 736 cod were tagged and 116 (15.8%) were recaptured. Recapture rates were 11.7-16.8% among the three banks. In March, 561 cod were tagged, and 64 (11.4%) were recaptured. Recapture rates were 8.7-14.2% among the three banks.

SIZE AND AGE COMPOSITION

In the Area 4B experiments of 1978 and 1979, size compositions of cod tagged and released were bimodal with modes at 23 or 26 cm and 44 cm (Fig. 4, Table 2)--corresponding, respectively, to age-classes 1 and 2 (see Fig. 10 in Beamish et al. 1978 for verification). Few cod were tagged whose fork length exceeded 54 cm (age>2). Size ranges for individual age-classes were arbitrarily set at: <34 cm for age-class 1; 34-54 cm for age-class 2; and > 54 cm for age-class >2.

In the Area 3C-N experiment of 1979, size composition of tagged cod was also bimodal--44 and 56 cm (Fig. 5, Table 2), corresponding to age-2 and age->2 cod. Few age-1 cod were caught or tagged. Size ranges for individual age-classes were arbitrarily set at: <31 cm for age-class 1; 31-54 cm for age-class 2; and > 54 cm for age-class >2.

Age compositions of cod tagged and released generally reflected the catches from which the tagged cod were selected. The following text table provides the evidence:

		Age composition (%)				
Experiment	Category	1	2	>2	Total	N
4B/1978	Catch	48.6	47.8	3.6	100.0	1,378
	Releases	53.0	45.0	2.1	100.1	974
4B/1979	Catch	43.3	53.2	3.5	100.0	1,605
	Releases	40.5	58.6	0.9	100.0	1,108
3C-N/1979	Catch	4.7	46.9	48.4	100.0	3,992
	Releases	5.6	67.7	26.7	100.0	1,297

Notable are the low proportions of age-> 2 cod in the catches from Area 4B, and of age-1 cod in the catches from Area 3C-N. The relatively poor catches of age-1 and age-2 cod in area 3C-N reflect in part the low abundance of the 1978 and 1977 year-classes, as verified by the small annual cod landings from area 3C-N during 1979-83 (Fig. 6).

Among grounds within Area 3C-N, size composition of tagged cod was variable (Fig. 5, Tables 3 and 4). Few age-1 or age-2 cod were tagged on Amphitrite Bank or at Clo-oose. These two grounds are the only known spawning grounds in Area 3C-N, and apparently few juvenile cod were mingling with the spawning adults during this study. Big Bank, on the other hand, provided most of the juvenile cod tagged during February and March. Big Bank is an important feeding ground for cod during April-September (Westrheim and Foucher 1983).

PRE-RELEASE MORTALITY RATES

Among experiments. Pre-release mortality rates (age-classes combined) were 15.6% for Swanson Channel 1978 (excluding cod held overnight), 12.0% for Swanson Channel 1979, and 24.5% for Area 3C-N 1979 (Table 5). Each of the Swanson Channel rates differed significantly ($P<.01$) from that for Area 3C-N, and differed between themselves.

Within area 3C-N (combining months), pre-release mortality rates were 15.1% for Amphitrite Bank, 30.1% for Big Bank, and 13.9% for Clo-oose (Table 5). Amphitrite Bank and Clo-oose rates differed significantly ($P<.01$) from that for Big Bank, but not significantly ($P>.70$) among themselves. Among months, Chi-square tests indicated significant differences ($P<.01$) only for Big Bank (Table 6).

Among age-classes. Pre-release mortality rates varied inversely with age-class within major experiments (Table 7), and among sub-experiments within Area 3C-N (Table 8). For major experiments, pre-release mortality rates were 17.7-36.5% for age-class 1, 6.7-27.0% for age-class 2, and 0-13.5% for age-class >2. All Chi-square tests, but that for 1978 (age 1 vs 2), indicated significantly ($P<.05$) different rates among age-classes within major experiments. For the three sub-experiments (months combined) in Area 3C-N, only four tests were feasible due to the small numbers of cod tagged, and only one yielded a significant difference--age-class 1 vs >2 on Amphitrite Bank. Other tests were: age-class 2 vs >2 on Amphitrite Bank ($P>.50$); age-class 1 vs 2 ($P>.10$); and age-class 2 vs >2 ($P>.50$).

Within age classes. Pre-release mortality rates within age-classes (among experiments) were significantly larger ($P<.01$ or $<.05$) in Area 3C-N (all banks) than in Swanson Channel (Area 4B)--36.5% vs 17.7 and 20.0% for age-class 1; 27.0% vs 13.7% vs 6.7% for age-class 2; and 13.7 vs 0 and 0% for age-class >2 (Table 9; Appendix Tables 1-3).

For age-class 1, pre-release mortality rates for the two Swanson Channel experiments (17.7 and 20.0%) did not differ significantly ($P>.30$), nor did those for Big Bank (37.5%) and Amphitrite Bank (32.0%)--$P>.50$ (Table 9).

For age-class 2, the 1978 Swanson Channel mortality rate (13.7%) was significantly ($P<.01$) larger than that for the 1979 experiment (6.7%) (Table 9). Within Area 3C-N, the pre-release mortality rate on Big Bank

(29.4%) was significantly larger than those on Amphitrite Bank (15.5%, P<.01) and Clo-oose Ground (15.2%, P<.02) (Table 9). Evidently, the mortality rates for Amphitrite Bank (15.5%) and Clo-oose (15.2%) were not significantly different.

For age-class >2, pre-release mortality rates for Amphitrite Bank (13.4%) and Clo-oose Ground (12.4%) were not significantly different (P>.70) (Table 9). No other comparisons were testable.

Overnight holding. Pre-release mortality rates were higher for age-1 and age-2 cod held overnight in the 1978 Swanson Channel experiment--18.0 & 30.0% vs 17.7 & 13.7% (Table 10). However, a significantly higher rate only occurred for age-class 2 (30.0% vs 13.7, P<.01).

Double-tagging. Pre-release mortality rates were higher, but not significantly so, for double-tagged age-1 and age-2 cod than for age-1 and age-2 single-tagged cod in the 1978 Swanson Channel experiment--20.8 & 19.2% vs 17.7 & 17.3% (Table 11). Mortality rates for age-classes 1 (20.8%) and 2 (19.2%) were not significantly different (P>.30 and .95).

Summary. Pre-release mortality rates varied inversely with age-class; were generally lower in inshore waters; and among offshore grounds were higher for age-class 2 on the bank furthest offshore, presumably where sea conditions were rougher. The 1978 Swanson Channel mortality rates were not significantly affected by overnight holding or double-tagging, except age-2 cod held overnight. However, in all cases, mortality rates were higher for tagged cod held overnight or double-tagged.

RECAPTURE RATES

Among experiments (age-classes combined). Recapture rate for the Area 3C-N experiment (13.9%) was significantly smaller (P<.01) than that for Swanson 1978 (25.0%), but not so (P>.05) for Swanson 1979 (16.5%) (Table 12). Recapture rate for the Swanson 1979 experiment (16.5%) was significantly smaller (P<.01) than that for Swanson 1978 (25.0%). The low recapture rate for Swanson 1979 was attributed to less effective tag-recovery effort in Victoria during 1979 than in 1978. Appreciable quantities of Pacific cod caught in MSAs 18-20 are landed in both Vancouver, the major port, and Victoria. In Vancouver, where Port Liaison Officers are on duty, the numbers of tagged cod recaptured per tonne of cod landed during January-May were 0.21 in 1978 (for Swanson 1978 tags) and 0.24 in 1979 (for Swanson 1979 tags) (Table 13). However, in Victoria, where no Liaison Officer is stationed and PBS personnel are responsible for tag recaptures, the corresponding rates were 0.55 in 1978 and 0.16 in 1979. The relatively low recapture rate for the Area 3C-N 1979 experiment was attributed to rougher sea conditions which reduced the viability of cod held in tanks aboard ship.

Within Area 3C-N (months combined), recapture rate for the Amphitrite Bank sub-experiment (9.7%) was significantly smaller (P<.01) than that for Big Bank (16.2%), but not so (P>.20) for Clo-oose (12.8%) (Table 12). Recapture rates for Big Bank and Clo-oose sub-experiments were not significantly different (P>.20).

Among age-classes. Recapture rates were consistently smaller for age-1 cod than for age-2 cod for Swanson Channel 1978 (7.9% vs 42.0%, P<.01), Swanson Channel 1979 (3.9% vs 24.3%, P<.01), and Area 3C-N (8.2% vs 15.1%, P>.10), but not significantly so for the latter (Table 14). For Area 3C-N, recapture rates were not significantly different among age classes--age 1 (8.2%) vs age 2 (15.1%) (P>.30); age 1 (8.2%) vs age >2 (11.8%) (P>.30); and age 2 (15.1%) vs age >2 (11.8%) (P>.10). Within Area 3C-N (months combined), recapture rates of age-1 cod (0-9.1%) were smaller than those of age-2 cod (6.7-14.3%) or age >2 cod (11.4-25.0%) (Table 15). The only testable comparison, Big Bank (age 1 vs age 2), indicated no significant difference--9.1% vs 16.7%; P>.10. Recapture rates of age-2 cod were smaller than those of age >2 cod on Amphitrite Bank (6.7 vs 11.4%; P>.10) and Big Bank (16.7 vs 25.0%; not testable), but larger on Clo-ose Ground (14.3 vs 12.0%; P>.80). However, none of the testable comparisons were significantly different.

Three past experiments warrant comparison with respect to age-2 cod -- two in Area 4B and one in area 3C-N. No past experiments involved age-1.0 cod.

In Area 4B, during November-February 1954-55, 1,504 Pacific cod were tagged and released in Swanson Channel, and 369 (24.5%) were subsequently recaptured. Principal age-classes tagged were 2, 3, and 4 (adjusted to January-March), and recapture rates were similar for all size-classes (Westrheim 1982; Fig. 6). During February-March 1957-59, 2,248 cod were tagged and released at Porlier Pass (Trincomali Channel) and 306 (13.6%) were subsequently recaptured. Most of the cod tagged and released were age 2, and recapture rate was again consistent among all size classes. Thus the recapture rates for age-2 cod were approximately 24.5% and 13.6%, respectively, for the 1954-55 and 1957-58 experiments, compared to 40.8% and 23.7%; respectively, for the 1978 and 1979 experiments in the same region.

In Area 3C-N, only one past experiment involved appreciable quantities of age-2 cod (actually age 1.8)--September 1962 on Big Bank (Westrheim 1982; Table 20). Here, 179 age-2 cod (31-39 cm) were tagged, and 5.9% were subsequently recaptured. Recapture rate for age-2 cod in the February-March 1979 Big Bank experiment was substantially better--16.7%. Perhaps the higher recapture rates for the 1978-79 experiments resulted from improved handling procedures.

Within age-classes. Recapture rates within age classes (among experiments) exhibited no consistent pattern for the major experiments. For age-1 cod, recapture rate for the Area 3C-N experiment (8.2%) was not significantly larger than that for Swanson 1978 (7.7%; P>.80) or Swanson 1979 (3.9%; P>.10) (Table 16). For age-2 cod, recapture rate for the Area 3C-N experiment (15.1%) was significantly smaller (P<.01) than that for Swanson 1979 (24.3%), which in turn was significantly smaller (P<.01) than that for Swanson 1978 (42.9%). Needless to say, the Swanson 1978 recapture rate was significantly larger (P<.01) than that for Area 3C-N. No comparisons for age->2 cod were possible because too few were tagged and released.

Within Area 3C-N, recapture rate for age-2 cod was largest for the Big Bank sub-experiment (16.7%)--significantly so with respect to the Amphitrite sub-experiment (6.7%, P<.01), but not so with respect to the

Clo-oose sub-experiment (14.3%, P>.50) (Table 16). For age->2 cod, recapture rates for Amphitrite (11.4%) and Clo-oose (12.0%) sub-experiments were not significantly different (P>.80).

Overnight holding (Swanson 1978). Recapture rates were smaller for age-2 (37.7 vs 42.9%; P>.30) and total (20.0 vs 25.0%; P>.10) cod held overnight, but not significantly for either (Table 10). Too few cod were recovered to test the relationship for age >2 cod.

Double-tagging (Swanson 1978). Recapture rates exhibited no consistent pattern among age-classes, and in no case were recapture rates significantly different between single- and double-tagged cod (Table 11). Rates for single- and double-tagged age-1 cod were 8.5% and 6.6%, respectively (P>.80); 40.5% and 41.9% (P>.10) for age-2 cod; and 23.6% and 22.6% (P>.80) for combined age-classes. Too few age->2 cod were released and recaptured to justify a test.

Experiment results were inconclusive. Of the 24 recaptures from the Swanson Channel experiment, 22 had retained both tags, and two (both age-2) lacked the suture tag. One double-tagged cod was recaptured from the Yellow Rock experiment, and it had retained both tags.

Condition at release. Among major experiments (ages combined), recapture rates were always smaller for "handicapped"[1] cod, but only significantly so for Swanson 1978 and Area 3C-N 1979--30.0 vs 20.1, P<.01; 17.0 vs 14.9, P<.30; 15.9<10.0, P<.01 (Table 17). Among testable age classes, recapture rates were not significantly different for age-1 cod from Swanson Channel 1948 (7.9 vs 8.4; P<.01); significantly lower for age-2 handicapped cod (34.8 vs 49.4%, P<.01, Swanson 1978; 10.0 vs 17.8%, P<.01, Area 3C-N); not significantly different for age >2 cod from Area 3C-N (11.3 vs 13.1%, P>.50).

Within Area 3C-N, recapture rates among experiments (combined age-classes) exhibited no consistent pattern (Table 18). Recapture rates were significantly smaller for handicapped cod in the Big Bank sub-experiment (9.9% vs 20.1%, P<.01), but not so for Amphitrite (9.7% vs 9.6%, P=.98) or Clo-oose (11.9% vs 13.1%, P>.80) sub-experiments (Table 18). Among age-classes, only one test was feasible, applying to the Big Bank sub-experiment. Recapture rate was significantly lower for handicapped cod in age-class 2 (10.7% vs 20.5%, P<.01).

Summary. Recapture rates generally varied directly with age at release; were lower in offshore experiments; were generally unaffected by overnight holding or double-tagging in sheltered waters; and were generally lower for cod "handicapped" at time of release. The double-tagging experiment yielded inconclusive results, with respect to the shedding rate of the anchor tag.

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[1]"Handicaps" include any of the following: injury (with or without bleeding), gas-caused swelling, low viability, and loose tag.

TIME AT LIBERTY

Among experiments. Maximum time at liberty ranged from 8 to 13 quarter-years among experiments, but 83-93% of the recaptures occurred during the first four quarter-years (Table 19). Detailed records are contained in Appendix tables 7 and 8. Similar results were reported in all past cod-tagging experiments (Gosho 1976; Westrheim 1982) in the B.C.-Washington State region.

For the two Swanson Channel experiments, maximum times at liberty were 9 quarter-years (1978) and 8 quarter-years (1979), respectively (for 225 and 146 usable recaptures) (Table 19). Proportions recaptured during Year 1 were 87 and 93%, and during the quarter-year of tagging, 65 and 75%. Similar results were reported for the comparable January 1955 experiment in Swanson Channel (295 usable recaptures) (Westrheim 1982). Maximum time at liberty for the 1955 experiment was 12 quarter-years; 93% recaptured during Year 1; and 73% recaptured during the quarter-year of tagging.

For the Area 3C-N experiment, maximum time at liberty was 13 quarter-years (179 usable recaptures), but 83% were recaptured during Year 1, and 74% during Quarters II and III of Year 1. Conservation regulations inhibited recaptures during the quarter-year of tagging. The most comparable past experiment was that on Amphitrite Bank in May 1961 (209 usable recaptures) (Westrheim 1982), for which the maximum time at liberty was 8 quarter-years. The principal age classes were 3 and 2.

Among age-classes. Time at liberty was similar among age-classes--7-9 quarter-years for age-class 1; 6-13 for age-class 2; and 1-13 for age-class ->2 (Table 20). Furthermore, proportions recaptured during Year 1 were relatively high for all age-classes--42-67% for age-class 1; 82-99% for age-class 2; and 83-100% for age-class >2.

For age-class 1, maximum time at liberty among experiments was 7-9 quarter-years, for 5-39 usable recaptures (Table 20). Proportions recaptured during Year 1 were 67% for Swanson 1978 (39 usable recaptures), 42% for Swanson 1979 (N=14), and 60% for Area 3C-N 1979 (N=5). Recaptures were distributed fairly evenly among quarter-years.

For age-class 2, maximum time at liberty among experiments was 6-13 quarter-years for 131-180 usable recaptures (Table 20). Proportions recaptured during Year 1 were 84-99%--81 and 82% in the quarter-year of tagging for the two Swanson Channel experiments. For the Area 3C-N experiment, 76% were recaptured during Quarters II and III in Year 1, and results among sub-experiments were similar (Table 21).

For age-class >2, only 7 usable recaptures were reported from the two Swanson Channel experiments, and all were recaptured in the quarter-year of tagging (Table 20). For Area 3C-N, 69% of the usable recaptures were caught during Quarters II and III of Year 1.

Summary. Time at liberty was relatively short for all age-classes, and few cod were recaptured beyond the year of tagging. However, patterns of recapture differed among age-classes. Age-1 recaptures were fairly evenly distributed among quarter-years, while age-2 and age->2 recaptures were concentrated in the quarter-year of tagging, or the first two quarter-years when the tagged cod became available to the fishery. Singular exceptions among past experiments to the relatively high proportion of recaptures reported shortly after the tagging were experiments conducted in MSA 17 at Nanoose Bay (February-March 1955, 1958, 1959), MSA 19 (April 1960), and Big Bank (September 1962) (Westrheim 1982). The former two experiments involved cod emigrating shortly after being tagged, while in the latter case, cod landings at time of tagging were seasonally low, and remained so until Quarter II of the following year (there was no appreciable winter fishery at that time).

DISTRIBUTION

Among areas. A total of 457 tagged Pacific cod were recaptured for which location of recapture was determined, at least to major area (Table 22). Detailed records are contained in Appendix tables 7 and 8. Most of the cod were recaptured in the tagging area--94% for Swanson 1978, 86% for Swanson 1979, and 83% for area 3C-N 1979. Cod tagged in Area 4B were also recaptured in Areas 4A (6% and 8%) and 3C-N (0% and 7%). Cod tagged in Area 3C-N were also recaptured in Areas 4A (1%), 4B (8%), off the Washington-Oregon coast (areas 3C-S, 3B, 3A,; 6%), and off the northwest coast of Vancouver Island (3D, 1%). Paucity of recaptures precluded quantifying distribution, but for general reference, Figure 7 contains Canada-U.S. cod landings by month by statistical area for 1978-82.

Westrheim (1982) noted that in past Canadian and U.S. experiments during 1954-70 (34,216 cod tagged), proportions recaptured in the tagging area ranged from 88.1 to 99.7% for experiments involving at least 109 usable recaptures each. These experiments were conducted in Areas 4A, 4B, 3B, 3C-N, 5C, and 5D.

Among age-classes (outside tagging area). For the Area 4B experiments, no recaptures of age-class >2 were reported from outside the tagging area (Table 23). The four age-1 cod were all recaptured in Area 4A (Fig. 1). Of the 16 age-2 cod, 10 were recaptured in Area 4A, and 6 in Area 3C-N. For the Area 3C-N experiment, the single age-1 cod was recaptured off Oregon State (Area 3A-S). Of the 11 age-2 cod, 5 were recaptured in Area 4B, 2 in Area 4A, and 4 off Washington State (Areas 3B, 3A + 3B, and 3A). Of the 12 age->2 cod, 1 was recaptured in Area 4A, 5 in 4B, 4 off Washington State (Areas 3C-S, 3B, and 3A + 3B), and 2 in Area 3D.

Sub-experiments--Area 4B. Within Area 4B, four sub-experiments were identified--MSA 14 (Cape Lazo and Yellow Rock) and Swanson Channel in 1978; and Swanson Channel and Trincomali Channel in 1979 (Fig. 2). The MSA 14 sub-experiment produced only two usable recaptures both at Yellow Rock. One had been released at Cape Lazo and the other at Yellow Rock.

The 1978 Swanson Channel sub-experiment yielded 219 usable recaptures--79.9% from Swanson Channel and 90.3% from MSA 18 (Fig. 2, Table 24). Other recaptures were reported from Trincomali Channel (MSA 17, 0.9%), MSA 19 (Juan de Fuca Strait, 0.9%), and Area 4A (MSA 80, S.E. Georgia Strait, 6.4%).

The 1979 Swanson Channel sub-experiment yielded 71 usable recaptures--43.7% from Swanson Channel and 84.6% from all locations in MSA 18. Other recaptures were reported from MSA 19 (1.4%), MSA 80 (9.9%), and Area 3C-N (2.8%).

The 1979 Trincomali Channel sub-experiment yielded 19 usable recaptures--21.1% from Trincomali Channel. Other recaptures were reported from MSA 18 (21.1%; 15.8% from Swanson Channel), and 21.1% from Area 3C-N (5.3% from Swiftsure Bank).

Sub-experiments--Area 3C-N. From the Amphitrite Bank sub-experiment, 32 usable recaptures were reported--59.3% within Area 3C-N, (15.6% each from Amphitrite Bank and Big Bank) (Table 25). Other recaptures were reported from Areas 3D (6.3%), 3C-S (3.1%), 3A + 3B (6.3%), 4A (MSA 86, 3.1%), and 4B (MSA 20, 6.3%; MSA 19, 9.4%).

From the Big Bank sub-experiment, 98 usable recaptures were reported--84.6% within Area 3C-N (48.0% from Big Bank). Other recaptures were reported caught off Washington State (Areas 3A-N, 3B; 3.0%), off Oregon State (Area 3A-S, 1.0%), Area 4B (3.0%), and Area 4A (1.0%).

From the Clo-oose Ground sub-experiment, 16 recaptures were reported--63.1% from Area 3C-N (none from Clo-oose). Other recaptures were reported from off Washington State (Areas 3C-S, 3B; 12.6%) and Area 4B (25.1%).

Among quarter-years. Overall, qualitative distribution of recaptures was fairly uniform among quarter-years and major statistical area--5 "positives"(+) in Quarter I, and 8, 7, and 5, respectively, in the succeeding quarter-years (Table 26). Recaptures were reported from all four quarter-years in Areas 4A and 4B (from Area 4B experiments), and Area 3C-N (from the Area 3C-N experiment). Among sub-experiments in Area 4B, dispersion was greatest during Quarter I for the two Swanson Channel experiments--7 "positives" (+) versus 2, 3, and 2 for the 1978 experiment, and 4 versus 2, 2, and 2 for the 1979 experiment (Table 27). Recaptures from the small 1979 Trincomali sub-experiment were reported only from Quarters I (1 "positive") and II (4 "positives"). Among the 3C-N sub-experiments, distribution of recaptures was relatively uniform among quarter-years (Table 28). Greatest dispersion occurred during Quarters I (3 "positives") and II (3 "positives") for the Amphitrite Bank sub-experiment; Quarters II (5 "positives") and IV (5 "positives") for the Big Bank sub-experiment; and Quarter III (3 "positives") for the Clo-oose sub-experiment.

Summary. For all three experiments, the recaptured cod exhibited little dispersion. Among experiments, 83-94% were recaptured in the major statistical area of tagging. Age compositions of emigrants from the Area 4B

tagging areas were similar to those of the non-emigrants, but a greater proportion of age->2 had emigrated from Area 3C-N. Among sub-experiments, the two Swanson Channel experiments (1978 and 1979) yielded similar dispersion patterns. The Area 3C-N sub-experiments indicated considerable migration among trawling grounds within Area 3C-N. Among quarter-years, dispersion was greatest during Quarter I in the Area 4B experiments, probably as a reflection of landings (Fig. 7). For Area 3C-N experiments, dispersion was fairly uniform among Quarters II-IV. Recaptures during Quarter I were inhibited by conservation regulations which curtailed trawling in Area 3C-N. Interestingly, Swanson Channel experiments yielded recaptures in MSA 19 (Juan de Fuca Strait) during Quarters I-III, while Area 3C-N experiments yielded recaptures only during Quarter III and IV. This suggests that some Swanson Channel cod spend part of the feeding season in Area 3C-N. Further evidence of some Area 4B cod "summering" in Area 3C-N was reported by Westrheim (1982).

GROWTH

Growth analysis of recaptured Pacific cod tagged in the Area 4B and Area 3C-N experiments was constrained by the few recaptures at liberty one year or more. Recaptures were arrayed by "age" at tagging and quarter-year of recapture, beginning with Quarter III, Year 1 (Table 29). There is a general consistency to the data, as indicated by the following:

	Age (y)		
	1.0	2.0	3.0
Area 4B:	26.3 →	45.6	-
	-	43.7→	61.4
(Ketchen 1961)	(26.8)	(49.6)	(61.4)
Area 3C-N:	26.0 →	46.0	-
	-	42.0 →	54.3

For example, in the Area 4B experiment, age-1 cod recaptured after one year at liberty had a mean length of 26.0 cm when tagged, and 47.2 cm ($\Delta\bar{L}$=21.2 cm) when recaptured. Age-2 cod recaptured after one year at liberty had a mean length of 43.7 cm at tagging, and 61.4 cm ($\Delta\bar{L}$=17.7 cm) at recapture. Ketchen (1961) reported similar values based on tagging experiments conducted in Area 4B during 1954-58.

Area 3C-N data were similar to Area 4B data.

Results of the modified Munro (1982) method, employed to estimate the von Bertalanffy growth parameters K and L_∞ (assuming t_0=0), are as follows:

Area	K	L_∞	Source
4B	0.447 (0.56-0.71)	86 (72.8-77.4)	Table 30 (Ketchen 1961)
3C-N	0.494	74 cm	Table 31

Relevance of these results is difficult to assess because of the paucity of data. Ketchen (1984) noted considerable variability in growth among year-classes of tagged cod in Hecate Strait, based on substantially larger experiments.

RESULTS AND DISCUSSION

The principal result of the three 1978-79 experiments was the indication that production-scale tagging of juvenile cod was feasible, under favorable conditions.

Pre-release mortality rates were relatively high (17.7-36.5%) for age-1 cod but moderate (6.7-27.0%) for age-2 cod. Furthermore, these rates were substantially higher on the offshore grounds (Area 3C-N)--36.5% vs 17.7 and 20.0% for age-1 cod; 27.0% vs 13.7 and 6.7% for age-2 cod. The higher rates in the offshore areas were attributed primarily to rougher sea conditions during winter.

Recapture rates were unacceptably low for age-1 cod (3.9-8.2%), regardless of tagging location, but satisfactory for age-2 cod (15.1-42.9%). Indeed, the offshore experiment yielded similar recapture rates for age-2 (15.1%) and age->2 (11.8%) cod. Inshore experiments yielded substantially higher recapture rates for age-2 cod than did the offshore experiment. Overnight holding during the 1978 inshore experiment reduced recapture rates only slightly. In all cases, recapture rates of "handicapped" cod (injury, low viability, or loose tag) were lower, and significantly so in most cases.

Maximum time at liberty was 8-13 quarter-years among experiments, but 83-93% of the recaptures were reported during Year 1, regardless of age-class. For age-1 cod, distribution of recaptures was relatively uniform among quarter-years, with maxima occurring in Quarter 1, Year 2, for the two inshore experiments. For age-2 cod, 77 and 82%, respectively, of the recaptures were reported during the quarter-year of tagging for the two inshore experiments. For the offshore experiment, 40% were reported during Quarter II, Year 1, and

36% during Quarter III, Year 1. Trawl regulations restricted recaptures in Area 3C-N during the quarter-year of tagging, although 2% were recaptured elsewhere. The relatively large proportions of the recaptures reported during the quarter-year, or adjacent quarter-year, of tagging were noted in most past experiments as well, and have been attributed to the relatively high vulnerability to trawling of recently released, tagged cod.

In summary, these results suggest that a successful experiment could be undertaken utilizing age-1 cod in September (at age 1.8), providing the age-class is suitably abundant. Winter, with its frequent storms, is not a desirable time to tag juvenile cod. Also, age-2 cod would not be a desirable target in any season because recruitment of this age-class becomes substantial in winter or early spring (age 2.0-2.6). Four advantages are apparent. First, age-1.8 cod will be ca. 35-40 cm long, and hence more viable for tagging. Second, seas are relatively calm during September. Third, trawling effort is declining rapidly, and will not increase substantially until about February in the next year. Hence, the tagged fish would not be exposed to a substantial fishery at release, as has occurred in most past experiments. Fourth, recruitment begins some 4-6 months after tagging. The September 1962 experiment on Big Bank is an encouraging example. There, 250 cod (mostly age 1.8) were tagged and released--method of, and conditions at, tagging are unknown. Recaptures extended to Quarter I, Year 4 (1965), and 30% were recaptured after Year 2.

Ancillary results with respect to stock delineation and growth were similar to those reported for past experiments in the B.C.-Washington State region.

Distribution of recaptures indicated that 83-94% were reported from the major area of tagging. Cod tagged in Area 4B were also recaptured in the U.S. portion of Georgia Strait (4A), and off the southwest coast of Vancouver Island (3C-N). Cod tagged off the southwest coast of Vancouver Island were also recaptured off the northwest coast of Vancouver Island (3D), off the coasts of Washington and Oregon (3A, 3B, 3C-S), and in the Canadian (4B) and U.S. (4A) portion of Georgia Strait. Within Area 4B, most of the recaptures were reported within the minor area of tagging, while in Area 3C-N, there was a substantial exchange between Amphitrite, Big and Swiftsure banks.

Growth analysis was inhibited by the few recaptures at liberty a reasonable time. However, the sketchy results were consistent among themselves and with past studies in Area 4B (Ketchen 1961). The Munro (1982) method yielded estimates of von Bertalanffy growth parameters as: $K=0.447$ and $L_\infty=86$ cm for Area 4B; and $K=0.494$ and $L_\infty=74$ cm for Area 3C-N. The validity of these estimates has not been established. Ketchen (1984) noted the confounding variables affecting growth analysis by tag recaptures in his analysis of several large experiments, with adult cod, conducted in Hecate Strait during 1960-68.

ACKNOWLEDGMENTS

The author gratefully acknowledges the assistance provided by R. P. Foucher and W. R. Harling, who performed the initial compilations. R. P. Foucher, B. M. Leaman, G. A. McFarlane, and W. E. Ricker reviewed the manuscript.

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Table 1. Inventory of Pacific cod tagging experiments conducted during January-March 1978-79.

Time	Location	Numbers Released	Numbers Recaptured	% Recaptured
Jan-Feb 1978	Area 4B	974	231	23.7
	Swanson Channel	959	229	23.9
	Yellow Rock	12	1	8.3
	Cape Lazo	3	1	33.3
Jan 1979	Area 4B	1,109	178	16.5
	Swanson Channel	974	161	16.5
	Trincomali Channel	135	17	12.6
Feb 1979	Area 3C-N	736	116	15.6
	Amphitrite Bank	120	14	11.7
	Big Bank	582	98	16.8
	Clo-oose	34	4	11.8
Mar 1979	Area 3C-N	561	64	11.4
	Amphitrite Bank	263	23	8.7
	Big Bank	183	26	14.2
	Clo-oose	115	15	13.0
Grand Total		3,380	589	17.4

Table 2. Length-frequencies (nos.) of tagged and released (T), and recaptured (R), Pacific cod in the 1978-79 experiments. (Lengths at the time of tagging.)

Fork Length (cm)	4B 1978			4B 1979			3C-N 1979		
	T	R	%R	T	R	%R	T	R	%R
14	1	-		-	-		-	-	
7	1	-		1	-		7	-	
20	22	1		53	-		19	1	
3	178	14		217	4		15	1	
6	254	18		145	12		17	2	
9	58	7		30	3		15	2	
32	2	0		3	0		28	3	
5	4	2		9	1		63	5	
8	17	7		57	9		157	18	
41	75	33		164	45		181	28	
4	196	91		239	56		199	38	
7	115	38		141	35		94	18	
50	24	11		34	11		82	16	
3	7	2		5	1		74	7	
6	12	4		3	0		113	15	
9	5	1		4	0		93	5	
62	2	1		2	1		57	9	
5	1	1		1	-		47	8	
8	-	-		-	-		22	2	
71	-	-		-	-		9	1	
4	-	-		-	-		3	1	
7	-	-		-	-		1	-	
80	-	-					1	-	
Total	974	231	23.7	1,109[a]	178	16.1	1,297	180	13.9
Age 1[b]	516	40	7.8	449	19	4.5	73	6	8.2
Age 2[c]	438	184	42.2	649	158	24.3	888	133	15.1
Age > 2[d]	20	7	35.0	10	1	10.0	346	41	12.0

[a]Includes 1 fish of unknown length.
[b]<34 cm for 4B; <31 cm for 3C-N.
[c]34-54 cm for 4B; 31-54 cm for 3C-N.
[d]>54 cm.

Table 3. Length-frequencies (nos.) of Pacific cod tagged and released (T), and recaptured (R), in the Area 3C-N February 1979 experiments, by sub-experiment. (Lengths at time of tagging.)

Fork Length (cm)	Amphitrite			Big Bank			Clo-oose		
	T	R	%R	T	R	%R	T	R	%R
17	5	-		2	-		-	-	
20	7	1		11	-		-	-	
3	1	0		13	1		1	-	
6	1	0		12	2		0	-	
9	3	0		7	1		0	-	
32	0	0		23	3		0	-	
5	0	0		48	4		0	-	
8	4	0		110	15		0	-	
41	1	0		131	20		0	-	
4	10	2		138	28		0	-	
7	3	2		53	13		0	-	
50	18	2		21	8		2	-	
3	20	0		6	1		6	2	
6	30	4		4	1		5	0	
9	13	1		1	0		3	1	
62	4	2		0	0		4	0	
5	-	-		1	1		6	0	
8	-	-		1	-		5	0	
71	-	-		-	-		1	0	
4	-	-		-	-		0	0	
7	-	-		-	-		1	1	
Total	120	14	11.7	582	98	16.8	34	4	11.8
Age 1[a]	17	1	5.9	45	4	8.9	1	-	-
Age 2[b]	56	6	10.7	530	92	17.4	8	2	25.0
Age >2[c]	47	7	14.9	7	2	28.6	25	2	8.0

[a] <31 cm.
[b] 31-54 cm.
[c] >54 cm.

Table 4. Length-frequencies (nos.) of Pacific cod tagged and released (T), and recaptured (R), in the Area 3C-N March 1979 experiments, by sub-experiment. (Lengths at time of tagging.)

Fork Length (cm)	Amphitrite			Big Bank			Clo-oose		
	T	R	%R	T	R	%R	T	R	%R
20	-	-		1	-		-	-	
3	-	-		0	-		-	-	
6	-	-		4	-		-	-	
9	-	-		5	1		-	-	
32	-	-		5	0		-	-	
5	1	-		13	1		1	-	
8	1	-		41	3		1	-	
41	5	1		43	7		1	-	
4	9	1		37	7		5	-	
7	18	0		18	3		12	-	
50	12	0		13	2		16	4	
3	28	0		2	2		12	2	
6	50	5		0	-		24	5	
9	52	3		1	-		23	0	
62	40	5		-	-		9	2	
5	33	6		-	-		7	1	
8	15	1		-	-		1	1	
71	6	1		-	-		2	-	
4	2	-		-	-		1	-	
7	0	-		-	-		-	-	
80	1	-		-	-		-	-	
Total	263	23	8.7	183	26	14.2	115	15	13.0
Age 1[a]	-	-	-	10	1	10.0	-	-	-
Age 2[b]	64	2	3.1	172	25	14.5	48	6	12.5
Age >2[c]	199	21	10.6	1	-	-	67	9	13.4

[a] <31 cm.
[b] 31-54 cm.
[c] >54 cm.

Table 5. Chi-square tests of pre-release mortality rates among experiments (combined age classes) for Pacific cod tagged in Swanson Channel (Area 4B) and Area 3C-N, January-March 1978-79. (Source: Appendix tables 1-6.)

Test	T[a]	D[b]	D/T	k^2	P[c]
Area 3C-N vs:	1,718	421	.245	-	-
Swanson 1978[d]	883	138	.156	27.2	<.01
Swanson 1979	1,107[e]	133	.120	66.6	<.01
Swanson 1978[d] vs:			.156		
Swanson 1979	1,107	133	.120	5.454	<.02
Big Bank vs:	1,094	329	.301	-	-
Amphitrite	451	68	.151	37.6	<.01
Clo-oose	173	24	.139	19.5	<.01
Amphitrite vs:			.151		
Clo-oose	173	24		0.144	>.70

[a] T = number tagged.
[b] D = number died.
[c] P = probability of a larger k^2 due to chance alone.
[d] Excluding fish held overnight.
[e] Including 1 fish of unknown length.

Table 6. Chi-square tests of pre-release mortality rates and recapture rates among months, by ground, for Pacific cod tagged and released in Area 3C-N, February-March 1979.

	Amphitrite		Big Bank		Clo-oose		3C-N	
	Feb	Mar	Feb	Mar	Feb	Mar	Feb	Mar
Nos. tagged	142	309	790	304	54	119	986	732
Nos. died	22	46	208	121	20	4	250	171
%	15.5	14.9	26.5	39.8	37.5	3.4	25.4	23.6
χ^2	0.028		19.0		-		0.903	
p^a	>.80		<.01		-		>.30	
Nos. released	120	263	582	183	34	115	736	561
Nos. recaptured	14	23	98	26	4	15	116	64
%	11.7	8.7	16.8	14.2	11.8	13.0	15.8	11.4
χ^2	0.806		0.709		-		5.046	
p^a	>.30		>.30		-		<.05	

[a] p = probability of a larger χ^2 due to chance alone.

Table 7. Chi-square tests of pre-release mortality rates among age-classes for Pacific cod tagged in Swanson Channel (Area 4B) and Area 3C-N (all-banks), January-March 1978-79. (Source: Appendix tables 1-3.)

Test		Age (y)[a] 1	2	>2	Total
			Area 4B - Swanson Channel		
1978	% died	17.7	13.7	-	15.6
	(Nos. tagged)[b]	(457)	(416)	(10)	(883)
versus age 2:	p[c]	>.10	-	-	-
1979	% died	20.0	6.7	0	12.0
	(Nos. tagged)	(451)	(645)	(10)	(1,107)[d]
versus age 2:	p[c]	<.01	-	-	-
			Area 3C-N - All-banks		
1979	% died	36.5	27.0	13.5	24.5
	(Nos. tagged)	(115)	(1,203)	(400)	(1,718)
versus age 2:	p[c]	<.05	-	-	-
versus age >2:	p[c]	<.01	<.01	-	-

[a]Age 1 =<34 cm in Area 4B, <31 cm in Area 3C-N; age 2 = 34-54 cm in Area 4B, 31-54 cm in Area 3C-N; age >2 = >54 cm.

[b]Excluding cod held overnight.

[c]p = probability of a larger value of χ^2 due to chance alone.

[d]Including 1 fish of unknown length.

Table 8. Chi-square tests of pre-release mortality rates among age-classes, by ground, for Pacific cod tagged in Area 3C-N, February-March 1979. (Source: Appendix tables 4-6.)

Test		Age (y)a 1	2	>2	Total
			Amphitrite Bank		
	% died	32.0	15.5	13.4	15.1
	(Nos. tagged)	(25)	(142)	(284)	(451)
versus age >2:	p^b	<.02	>.50	-	-
			Big Bank		
	% died	37.5	29.4	27.3	30.1
	(Nos. tagged)	(88)	(995)	(11)	(1,094)
versus age 2:	p^b	>.10	-	-	-
			Clo-oose Ground		
	% died	50.0	15.2	12.4	13.9
	(Nos. tagged)	(2)	(66)	(105)	(173)
versus age >2:	p^b	-	>.50	-	-

[a]Age 1 = <31 cm; age 2 = 31-54 cm; age >2 = >54 cm.
[b]p = probability of a larger χ^2 value due to chance alone.

Table 9. Chi-square tests of pre-release mortality rates among experiments, by age-class, in Areas 4B and 3C-N, January-March 1978-79. (Source: Appendix tables 1-6.)

Test	T[a]	D[b]	D/T	χ^2	P[c]
			Age-class 1		
3C-N (all-banks) vs:	115	42	.365	-	-
Swanson 1978[d]	457	81	.177	19.2	<.01
Swanson 1979	451	90	.200	14.1	<.01
Swanson 1978 vs:	(see above)				
Swanson 1979	451	90	.200	0.739	>.30
Big Bank vs:	88	33	.375	-	-
Amphitrite	25	8	.320	0.255	>.50
			Age-class 2		
3C-N (all-banks) vs:	1,203	325	.270	-	-
Swanson 1978	416	57	.137	30.4	<.01
Swanson 1979	645	43	.067	109	<.01
Swanson 1978 vs:	(see above)				
Swanson 1979	645	43	.067	14.7	<.01
Big Bank vs:	995	293	.294	-	-
Amphitrite	142	22	.155	12.1	<.01
Clo-oose	66	10	.152	6.200	<.02
			Age-class >2		
Amphitrite vs:	284	38	.134	-	-
Clo-oose	105	13	.124	0.067	>.70

[a] T = numbers tagged.

[b] D = numbers died.

[c] P = probability of a larger χ^2 due to chance alone.

[d] Excluding cod held overnight.

Table 10. Chi-square tests of pre-release mortality rates and recapture rates, by age-class and age-classes combined, for Pacific cod held and not held overnight prior to release in the 1978 Swanson Channel experiment.

	Age (y)[a]							
	1		2		>2		Total	
Held overnight:	No	Yes	No	Yes	No	Yes	No	Yes
Total tagged	457	161	416	110	10	7	883	278[b]
No. died	81	29	57	33	-	2	138	64
%	17.7	18.0	13.7	30.0	0	28.6	15.6	23.0
χ^2	0.007		16.3				8.041	
p[c]	>.90		<.01				<.01	
No. released	376	132	359	77	10	5	745	214
No. recaptured	29	11	154	29	3	3	186	43
%	7.7	8.3	42.9	37.7	30.0	60.0	25.0	20.0
χ^2	0.052		0.713				2.172	
p[c]	>.80		>.30				>.10	

[a]Age 1 = <34 cm; age 2 = 34-54 cm; age >2 = >54 cm.
[b]Excluding 38 fish which died due to a technical problem.
[c]p = probability of a larger χ^2 value due to chance alone.

Table 11. Chi-square tests of pre-release mortality rates and recapture rates, by age class and age classes combined, for Pacific cod single-tagged and double-tagged in the 1978 Swanson Channel experiment.

	Age (y)[a]							
	1		2		>2		Total	
Double-tagged:	No	Yes	No	Yes	No	Yes	No	Yes
Total tagged	541	77	474	52	15	2	1,030	131
No. died	94	16	81	9	2	-	177	25
%	17.7	20.8	17.3	19.2	13.3	-	17.2	19.1
χ^2	0.534		0.002		-		0.292	
P[b]	>.30		>.95		-		>.50	
No. released	447	51	393	43	13	2	853	106
No. recaptured	38	4	159	18	4	2	201	24
%	8.5	6.6	40.5	41.9	30.8	100	23.6	22.6
χ^2	-		0.032		-		0.045	
P[b]	-		>.80		-		>.80	

[a]Age 1 = <34 cm; age 2 = 34-54 cm; age >2 = > 54 cm.
[b]P=probability of a larger χ^2 value due to chance alone.

Table 12. Chi-square tests of recapture rates (age-classes combined) among experiments for Pacific cod tagged and released in Swanson Channel and Area 3C-N (all-banks), January-March 1978-79. (Source: Appendix tables 1-6.)

Experiment	TR[a]	R[b]	R/TR	χ^2	P[c]
Area 3C-N (all-banks)	1,297	180	.139		
Swanson 1978[d]	745	186	.250	39.5	<.01
Swanson 1979	974	161	.165	3.065	>.05
Swanson 1978	(see above)				
Swanson 1979	974[e]	161	.165	18.6	<.01
Amphitrite	383	37	.097		
Big Bank	765	124	.162	9.1	<.01
Clo-oose	149	19	.128	1.088	>.20
Big Bank	(see above)				
Clo-oose	149	19	.128	1.130	>.20

[a]TR=Tagged and released.
[b]R=Recaptured.
[c]P=probability of a larger χ^2 value due to chance alone.
[d]Excluding fish held overnight.
[e]Including one fish of unknown length.

Table 13. Recaptured tags (nos.) and Pacific cod landings (t) from Area 4B, by month and port, for year-1 of the January-February 1978, and January 1979 experiments in Area 4B.

	Month					
	Jan	Feb	Mar	Apr	May	Total
			Vancouver			
1978						
Tags (nos.)	19	35	23	8	2	87
Landings (t)	179	134	45	23	26	407
T/L	.11	.26	.51	.35	.08	.21
1979						
Tags (nos.)	17	48	4	1	11	81
Landings (t)	39	184	80	27	6	336
T/L	.44	.26	.05	.04	1.83	.24
			Victoria			
1978						
Tags (nos.)	35	23	24	5	-	87
Landings (t)	42	54	39	18	5	158
T/L	.83	.43	.62	.28	0	.55
1979						
Tags (nos.)	6	27	2	9	-	44
Landings (t)	74	126	28	38	1	267
T/L	.08	.21	.07	.24	0	.16

Table 14. Chi-square tests of recapture rates among age-classes, for Pacific cod tagged and released in Swanson Channel (Area 4B) and Area 3C-N (all banks), January-March 1978-79. (Source: Appendix tables 1-3.)

Year		Age (y)[a] 1	2	>2	Total
			Area 4B - Swanson Channel		
1978[b]	% recaptured (Nos. released)	7.9 (508)	42.0 (436)	40.0 (15)	23.9 (959)
versus age 2:	p[c]	<.01	-	-	-
1979	% recaptured (Nos. released)	3.9 (361)	24.3 (602)	10.0 (10)	16.5 (974)[d]
versus age 2:	p[c]	<.01	-	-	-
			Area 3C-N - All-banks		
1979	% recaptured (Nos. recovered)	8.2 (73)	15.1 (878)	11.8 (346)	13.9 (1,297)
versus age 2:	p[c]	>.10	-	-	-
versus age >2:	p[c]	>.30	>.10	-	-

[a]Age 1 = <34 cm for Area 4B, <31 cm for Area 3C-N; age 2 = 34-54 cm for Area 4B, 31-54 cm for Area 3C-N; age >2 = >54 cm.

[b]Including fish held overnight.

[c]Probability of a larger χ^2 value due to chance alone.

[d]Including 1 fish of unknown length.

Table 15. Chi-square tests of recapture rates among age classes, by ground, for Pacific cod tagged and released in Area 3C-N February-March 1979. (Source: Appendix tables 4-6.)

	Age (y)[a]			
	1	2	>2	Total
		Amphitrite Bank		
% Recaptured (Nos. released)	5.9 (17)	6.7 (120)	11.4 (246)	9.7 (3838)
versus age >2: P[b]	-	>.10	-	-
		Big Bank		
% Recovered (Nos. released)	9.1 (55)	16.7 (702)	25.0 (8)	16.2 (765)
versus age 2: P[b]	>.10	-	-	-
		Clo-oose Ground		
% Recovered (Nos. released)	0 (1)	14.3 (56)	12.0 (92)	12.8 (149)
versus age >2: P[b]	-	>.80	-	-

[a] Age 1 = <31 cm; age 2 = 31-54 cm; age >2 = >54 cm.
[b] P = probability of a larger χ^2 value due to chance alone.

Table 16. Chi-square tests of recapture rates among experiments, by age class, in Areas 4B and 3C-N, January-March 1978-79. (Source: Appendix tables 1-6.)

Experiment	TR[a]	R[b]	R/TR	x^2	p[c]
			Age-class 1		
3C-N (all-banks) versus:	73	6	.082	-	-
Swanson 1978[d]	376	29	.077	0.022	>.80
Swanson 1979	361	14	.039	2.603	>.10
Swanson 1978[c] versus:	(see above)				
Swanson 1979	361	14	.039	4.929	<.05
			Age-class 2		
3C-N (all banks) versus:	1,297	180	.151	-	-
Swanson 1978[c]	359	154	.429	147	<.01
Swanson 1979	602	146	.243	31.1	<.01
Swanson 1978[c] versus:	(see above)				
Swanson 1979	602	146	.243	36.4	<.01
Big Bank versus:	702	117	.167	-	-
Amphitrite	120	8	.067	7.948	<.01
Clo-oose	56	8	.143	0.213	>.50
Amphitrite versus:	(see above)				
Clo-oose	56	8	.143	2.682	>.10
			Age-class >2		
Amphitrite versus:	246	28	.114	-	-
Clo-oose	92	11	.120	0.022	>.80

[a]TR=tagged and released.
[b]R=recaptured.
[c]Probability of a larger x^2 due to chance alone.
[d]Excluding fish held overnight.

Table 17. Recapture rates (%), by age-class and experiment, for non-handicapped and handicapped Pacific cod tagged and released in Areas 4B and 3C-N, January-March 1978-79.

	Age (y)[a]							
	1		2		>2		Total	
Handicapped[b]:	No	Yes	No	Yes	No	Yes	No	Yes
Swanson Channel - 1978								
Nos. released	140	368	160	276	3	12	303	656
Nos. recaptured	11	31	79	96	1	5	91	132
%	7.9	8.4	49.4	34.8	33.3	41.7	30.0	20.1
χ^2	0.043		8.976		-		11.4	
p^c	>.80		<.01		-		<.01	
Swanson Channel - 1979								
Nos. released[d]	272	89	487	115	6	4	765	208
Nos. recaptured	12	2	118	28	-	1	130	31
%	4.4	2.2	24.2	24.3	0	25	17.0	14.9
χ^2	-		0.001		-		0.517	
p^c	-		>.98		-		>.30	
Area 3C-N (all banks) - 1979								
Nos. released	24	49	578	300	247	99	849	448
Nos. recaptured	4	2	103	30	28	13	135	45
%	16.7	4.1	17.8	10.0	11.3	13.1	15.9	10.0
χ^2	-		9.396		0.218		8.415	
p^c	-		<.01		>.50		<.01	

[a]Age 1 = <34 cm in Area 4B; <31 cm in Area 3C-N, age 2 = 34-54 cm in Area 4B, 31-54 cm in Area 3C-N; age >2 = >54 cm.

[b]Handicapped = injury, gas-caused swelling, low viability and/or loose tag.

[c]P = probability of a larger χ^2 due to chance alone.

[d]Excluding 1 fish of unknown length.

Table 18. Recapture rates (%), by age-class and sub-experiment, for non-handicapped and handicapped Pacific cod tagged and released in Area 3C-N, February-March 1979.

	Age (y)[a]							
	1		2		>2		Total	
Handicapped[b]:	No	Yes	No	Yes	No	Yes	No	Yes
Amphitrite Bank								
Nos. released	7	10	88	32	175	71	270	113
Nos. recaptured	1	-	6	2	19	9	26	11
%	14.3	0	6.8	6.3	10.9	12.7	9.6	9.7
χ^2	-		-		0.166		0.001	
p^c	-		-		>.50		>.98	
Big Bank								
Nos. released	16	39	450	252	6	2	472	293
Nos. recaptured	3	2	90	27	2	-	95	29
%	18.8	5.1	20.5	10.7	33.3	0	20.1	9.9
χ^2	-		10.0		-		13.9	
p^c	-		<.01		-		<.01	
Cle-oose Ground								
Nos. released	1	-	40	16	66	26	107	42
Nos. recaptured	-	-	7	1	7	4	14	5
%	0	-	17.5	6.3	10.6	15.4	13.1	11.9
χ^2	-		-		-		0.038	
p^c	-		-		-		>.80	

[a]Age 1 = < 34 cm in Area 4B; < 31 cm in Area 3C-N; age 2 = 34-54 cm in Area 4B; 31-54 cm in Area 3C-N; age >2 = > 54 cm.

[b]Handicapped = injury, gas-caused swelling, low viability, and/or loose tag.

[c]P = probability of a larger χ^2 due to chance alone.

Table 19. Time at liberty (%) among experiments, by quarter-year, for Pacific cod tagged and released during January-March 1978-79.

Year	Qtr.	Swanson Channel		Area 3C-N, 1979			
		1978	1979	Total	Amph.	Big	Clo.
1	I	69	75	2	3	1	5
	II	8	7	43	49	40	53
	III	8	8	31	14	37	26
	IV	5	3	7	14	6	5
2	I	9	5	2	5	1	0
	II	0	1	8	5	10	5
	III	T	1	4	5	4	0
	IV	0	1	2	0	2	5
3	I	T	-	0	0	-	-
4	I	-	-	1	5	-	-
Total		99	101	100	100	101	99
Usable recaptures[a]		225	146	179	37	123	19

[a]Recapture time known.

Table 20. Time at liberty (%) among major experiments, by quarter-year and age class[a], for Pacific cod tagged and released during January-March 1978-79.

Year	Qtr.	Swanson 1978			Swanson 1979			Area 3C-N		
		1	2	>2	1	2	>2	1	2	>2
1	I	13	81	100	7	82	100	-	2	2
	II	23	4	-	7	7	-	60	40	50
	III	21	6	-	14	8	-	0	36	19
	IV	10	4	-	14	2	-	0	6	12
2	I	28	6	-	43	1	-	0	1	5
	II	-	-	-	-	1	-	20	9	5
	III	3	-	-	7	-	-	20	4	2
	IV	-	-	-	7	-	-	-	2	2
3	I	3	-	-	-	-	-	-	0	0
4	I	-	-	-	-	-	-	-	1	2
Total		101	101	100	99	101	100	100	101	99
Usable recaptures[b]		39	180	6	14	131	1	5	132	42

[a]Age 1 = <34 cm for Swanson and <31 cm for 3C-N; age 2 = 34-54 cm for Swanson and 31-54 cm for 3C-N; age >2 = >54 cm.

[b]Recapture time known.

Table 21. Time at liberty (%) among major grounds in Area 3C-N, by quarter-year and age-class, for Pacific cod tagged and released January-March 1978-79.

		Amphitrite Bank			Big Bank			Clo-oose Ground		
Year	Qtr.	1	2	>2	1	2	>2	1	2	>2
1	I	-	-	3	-	1	-	-	12	-
	II	-	57	48	75	38	100	-	63	45
	III	-	0	17	0	39	-	-	25	27
	IV	-	14	14	0	6	-	-	-	9
2	I	-	0	7	0	1	-	-	-	0
	II	-	14	3	25	9	-	-	-	9
	III	100	0	3	-	4	-	-	-	0
	IV	-	0	0	-	2	-	-	-	9
3	I	-	0	0	-	-	-	-	-	-
4	I	-	14	3	-	-	-	-	-	-
Total		100	99	98	100	100	100	-	100	99
Usable Recaptures[a]		1	7	29	4	117	2	-	8	11

[a]Recapture time known

Table 22. Distribution (%), by major area, of Pacific cod tagged and released in Areas 4B and Area 3C-N during January-March 1978-79.

Recapture area	Tagging area		
	4B		3C-N
	1978	1979	1979
4A	6	8	1
4B	94	86	8
3C-N	-	7	83
3C-S	-	-	1
3B	-	-	2
3A & 3B	-	-	1
3A	-	-	2
3D	-	-	1
Total	100	101	99
Usable Recaptures[a]	221	90	146

[a]Recapture area known.

Table 23. Distribution (nos.), by age-class and major area, of tagged Pacific cod recaptured outside the tagging area from the Areas 4B and 3C-N experiments of January-March 1978-79.

Recapture area	Tagging area: 4B - 1978			4B - 1979			3C-N - 1979		
	1	2	>2	1	2	>2	1	2	>2
4A	1	5	-	3	5	-	-	2	1
4B	X	X	X	X	X	X	-	5	5
3C-N	-	-	-	-	6	-	X	X	X
3C-S	-	-	-	-	-	-	-	-	2
3B	-	-	-	-	-	-	-	2	1
3A & 3B	-	-	-	-	-	-	-	1	1
3A	-	-	-	-	-	-	1	1	-
3D	-	-	-	-	-	-	-	-	2
Total	1	5	-	3	11	-	1	11	12

Table 24. Distribution (%) of recaptured Pacific cod tagged in Area 4B during January-February 1978-79.

Recapture location	Tagging time and location		
	Jan-Feb 1978	Jan 1979	
	Swanson Channel	Swanson Channel	Trincomali Channel
Area 4B	1.4	1.4	36.8
MSA 17			
Trincomali Channel	0.9	-	21.1
MSA 18	1.8	14.1	-
Swanson Channel	79.9	43.7	15.8
Satellite Channel	6.8	25.4	5.3
Tumbo Channel	-	1.4	-
Prevost Passage	1.8	-	-
MSA 19	0.9	1.4	-
Area 4A	-	-	-
MSA 80	6.4	9.9	-
Area 3C-N	-	2.8	15.8
Swiftsure	-	-	5.3
Total	99.9	100.1	100.1
Usable Recaptures[a]	219	71	19

[a]Recapture location known.

Table 25. Distribution (%) of recaptured Pacific cod tagged in Area 3C-N, by sub-experiment, February-March 1979.

Recapture location	Tagging area		
	Amphitrite Bank	Big Bank	Clo-oose Ground
Area 3C-N	28.1	22.4	12.5
Amphitrite Bank	15.6	12.2	-
Big Bank	15.6	48.0	6.3
Deep Big Bank	-	1.0	-
Pachena	-	1.0	-
Swiftsure	6.3	7.1	43.8
Area 3D	6.3	-	-
Area 3C-S	3.1	-	6.3
Area 3B	-	2.0	6.3
Area 3A & 3B	6.3	-	-
Area 3A	-	2.0	-
Area 4A	-	-	-
MSA 86	3.1	1.0	-
Area 4B	-	1.0	-
MSA 20	6.3	1.0	6.3
MSA 19	9.4	-	18.8
MSA 14	-	1.0	-
Total	100.1	99.7	100.3
Usable recaptures[a]	32	98	16

[a]Recapture location known

Table 26. Distribution, by major area and quarter-year (combined years), for recaptured Pacific cod tagged in Areas 4B and 3C-N, January-March 1978-79.

Recapture area	Quarter-year I	II	III	IV
	Area 4B tagging			
4A	+	+	+	+
4B	+	+	+	+
3C-N	-	+	-	+
	Area 3C-N tagging			
4A	+	+	-	-
4B	+	-	+	+
3C-N	+	+	+	+
3C-S	-	-	+	-
3B	-	+	+	-
3A & 3B	-	+	-	-
3A	-	-	+	-
3D	-	+	-	-
Total (+)	5	8	7	5

Table 27. Distribution, by quarter-year, locality and/or MSA, in Areas 4B, 4A, and 3C-N of recaptured Pacific cod tagged in MSAs 17-S and 18 (Area 4B), during January-February 1978-79.

MSA	Locality	Swanson - 1978				Swanson - 1979				Trincomali - 1979			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
Area 4B													
17-S	Trincomali Channel	+	-	-	-	-	-	-	-	-	+	-	-
18	Unknown	+	-	-	-	+	-	-	-	-	-	-	-
	Swanson Channel	+	+	+	+	+	+	+	+	+	+	-	-
	Satellite Channel	+	-	-	-	+	-	+	-	-	+	-	-
	Tumbo Channel	-	-	-	-	+	-	-	-	-	-	-	-
	Prevost Channel	+	-	-	-	-	-	-	-	-	-	-	-
19	Victoria	+	-	+	-	-	+	-	-	-	-	-	-
Area 4A													
80	Unknown	+	+	+	+	-	-	+	+	-	-	-	-
Area 3C-N													
	Swiftsure	-	-	-	-	-	-	-	-	-	+	-	-
Total (+)		7	2	3	2	4	2	2	2	1	4	-	-

Table 28. Distribution, by quarter-year, locality and/or MSA, in Area 3C-N, 4A, and 4B of recaptured Pacific cod tagged in Area 3C-N during February-March, 1979, by sub-experiment.

MSA	Locality	Amphitrite Bank				Big Bank				Clo-oose Ground			
		I	II	III	IV	I	II	III	IV	I	II	III	IV
Area 3C-N													
	Amphitrite Bank	+	+	-	-	-	+	-	+	-	-	-	-
	Big Bank	-	+	+	-	-	+	+	+	-	+	-	-
	Deep Big Bank	-	-	-	-	-	+	-	-	-	-	-	-
	Pachena	-	-	-	-	-	+	-	-	-	-	-	-
	Swiftsure	-	+	-	-	-	+	-	+	-	+	-	-
Area 4A													
86	Unknown	+	-	-	-	-	-	-	-	-	-	+	-
Area 4B													
20	San Juan	+	-	-	-	-	-	-	-	-	-	+	-
19	Victoria	-	-	+	+	-	-	-	+	-	-	+	+
14	Cape Lazo	-	-	-	-	-	-	-	+	-	-	-	-
Total (+)		3	3	2	1	-	5	1	5	-	2	3	1

Table 29. Incremental growth ($\Delta\bar{FL}$ in cm), by age class, quarter-year and experiment, for Pacific cod recaptured from the Areas 4B and 3C-N experiments, January-March 1978-79.

		Year 1		Year 2				Year 3	
Age class	Par[a]	III	IV	I	II	III	IV	I	Total
					Area 4B				
1	$\Delta\bar{L}$	-	14.0	19.3	-	-	-	29.0	
(< 33 cm)	$\bar{L}$	-	23	26.3	-	-	-	25.0	
	N	-	1	4	-	-	-	1	6
2	$\Delta\bar{L}$	9.1	8.9	17.7	-	-	-	-	
(33-54 cm)	$\bar{L}$	42.7	45.4	43.7	-	-	-	-	
	N	7	7	3	-	-	-	-	17
Sub-total									28
					Area 3C-N				
1	$\Delta\bar{L}$	-	-	20	-	36.5	-	-	
(< 31 cm)	$\bar{L}$	-	-	26	-	24.5	-	-	
	N	-	-	1	-	2	-	-	3
2	$\Delta\bar{L}$	7.0	11.0	12.3	19.8	17.0	-	-	
(31-54 cm)	$\bar{L}$	42.9	41.4	42.0	40.0	41.0	-	-	
	N	38	4	6	4	3	-	-	56
Sub-total									59
Grand Total									87

[a]Parameters: $\Delta\bar{L}$ = mean increment in fork length (cm).
$\bar{L}$ = mean fork length (cm) at tagging.
N = numbers of cod recaptured.

Table 30. Munro growth analysis for Pacific cod recaptured from the Area 4B tagging experiment, January-February 1978-79.

$\bar{\ell}_m$[a] (cm)	$\bar{\ell}_r$[b] (cm)	r-m[c] (y)	Trial L_∞	Est. $\bar{K}$	S.D./$\bar{K}$
25.5	46.5	.75	110	.281	.193
26.0	47.2	1.00	100	.331	.184
27	52	1.50	90	.406	.177
28.0	40	.50	80	.527	.182
28	56	1.75	70	.770	.250
42.0	51.3	.50			
43.7	61.4	1.00	94	.372	.179
45.4	54.3	.75	92	.388	.178
			89	.415	.1775
			88	.425	.1769
			87	.436	.1772
			86	.447	.1766
			85	.458	.1775
			84	.470	.178
			82	.497	.179

[a]Fork length (cm) at tagging.
[b]Fork length (cm) at recapture.
[c]Time (y) at liberty.

Table 31. Munro growth analysis for Pacific cod recaptured from the Area 3C-N experiment, February-March 1979.

$\bar{\ell}_m$[a] (cm)	$\bar{\ell}_r$[b] (cm)	r-m[c] (y)	Trial L_∞	Est. $\bar{K}$	S.D./$\bar{K}$
24.5	61.9	1.50	100	.198	.583
26	46	1.00	90	.252	.544
39.0	51.5	.75	85	.294	.517
40.0	59.8	1.25	80	.356	.479
41.0	57.0	1.50	70	.786	.604
42.0	54.3	1.00			
43.1	50.1	.50	79	.372	.470
55.5	59.0	.75	78	.390	.462
56	64	1.75	77	.411	.452
(57)	(71)	(3.00)	76	.434	.445
60	69	1.25	75	.461	.439
60	69	1.25	74	.494	.435
61	62.5	.50	73	.534	.437
61	64	1.00	72	.587	.450
66	67	.75	71	.660	.492
67	69	.75			
(77)	(78)	(.50)			

[a]Fork length (cm) at tagging. (Whole numbers indicate single fish.)

[b]Fork length (cm) at recapture. (Whole numbers indicate single fish.)

[c]Time (y) at liberty.

[d]Values in parentheses not used in computations.

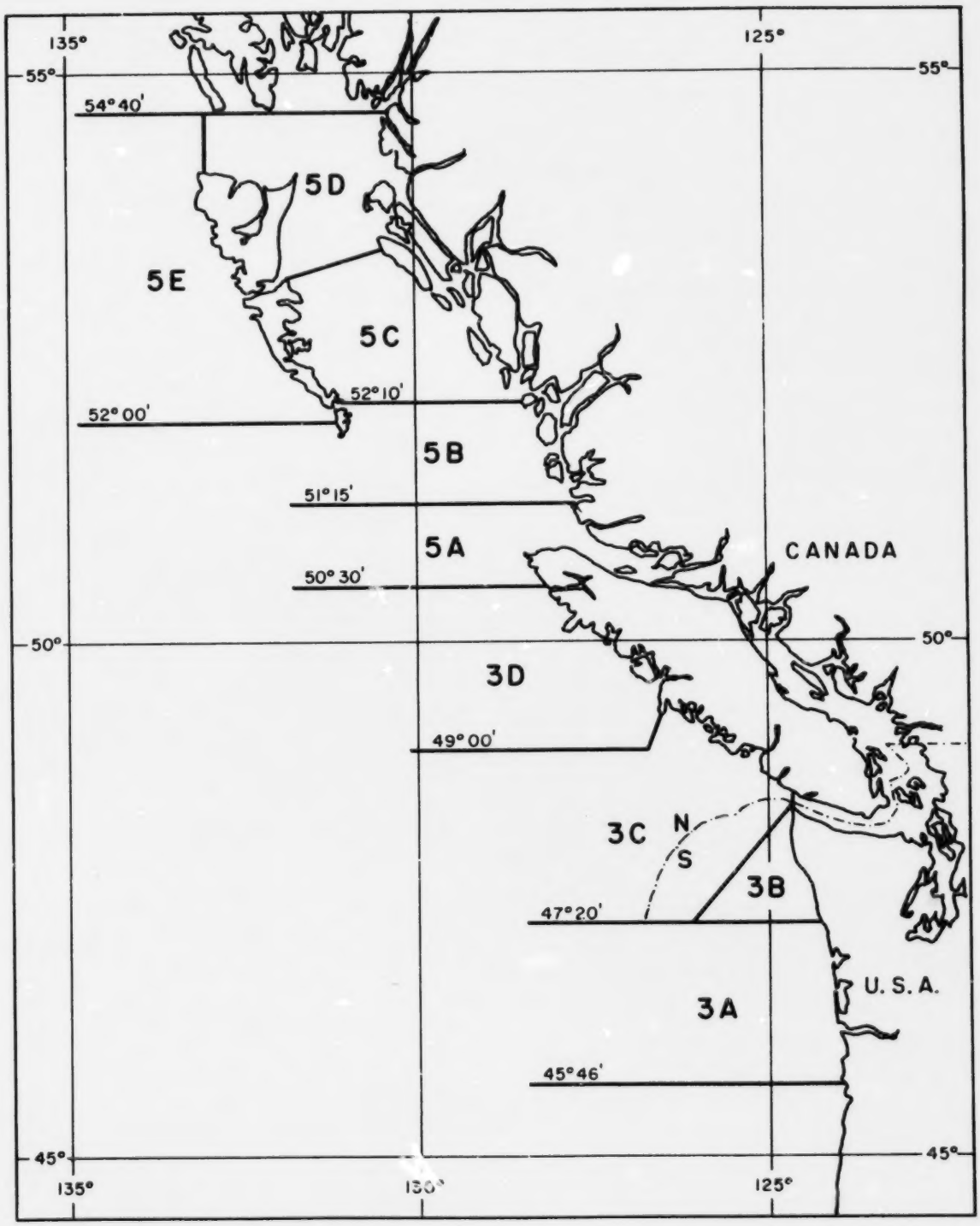

Fig. 1. Canada-U.S. groundfish statistical areas.

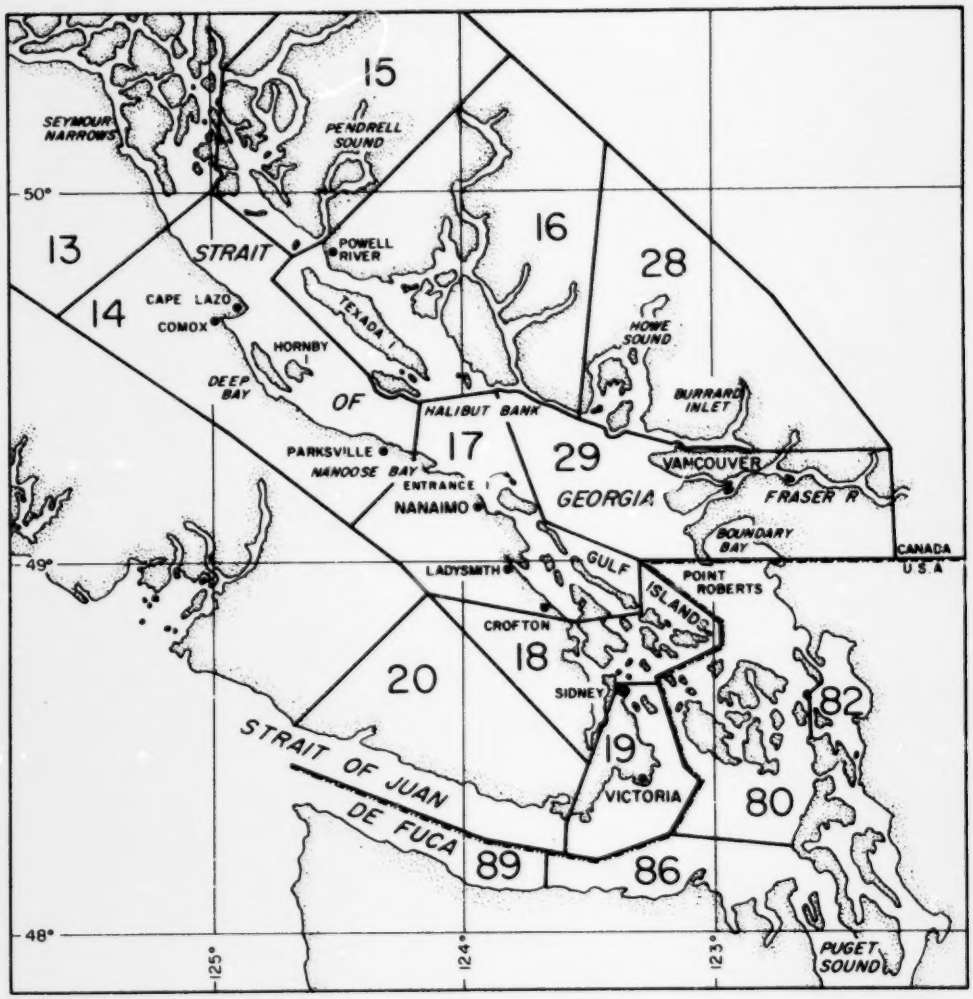

Fig. 2. Minor statistical areas in Areas 4A (U.S.) and 4B Canada.

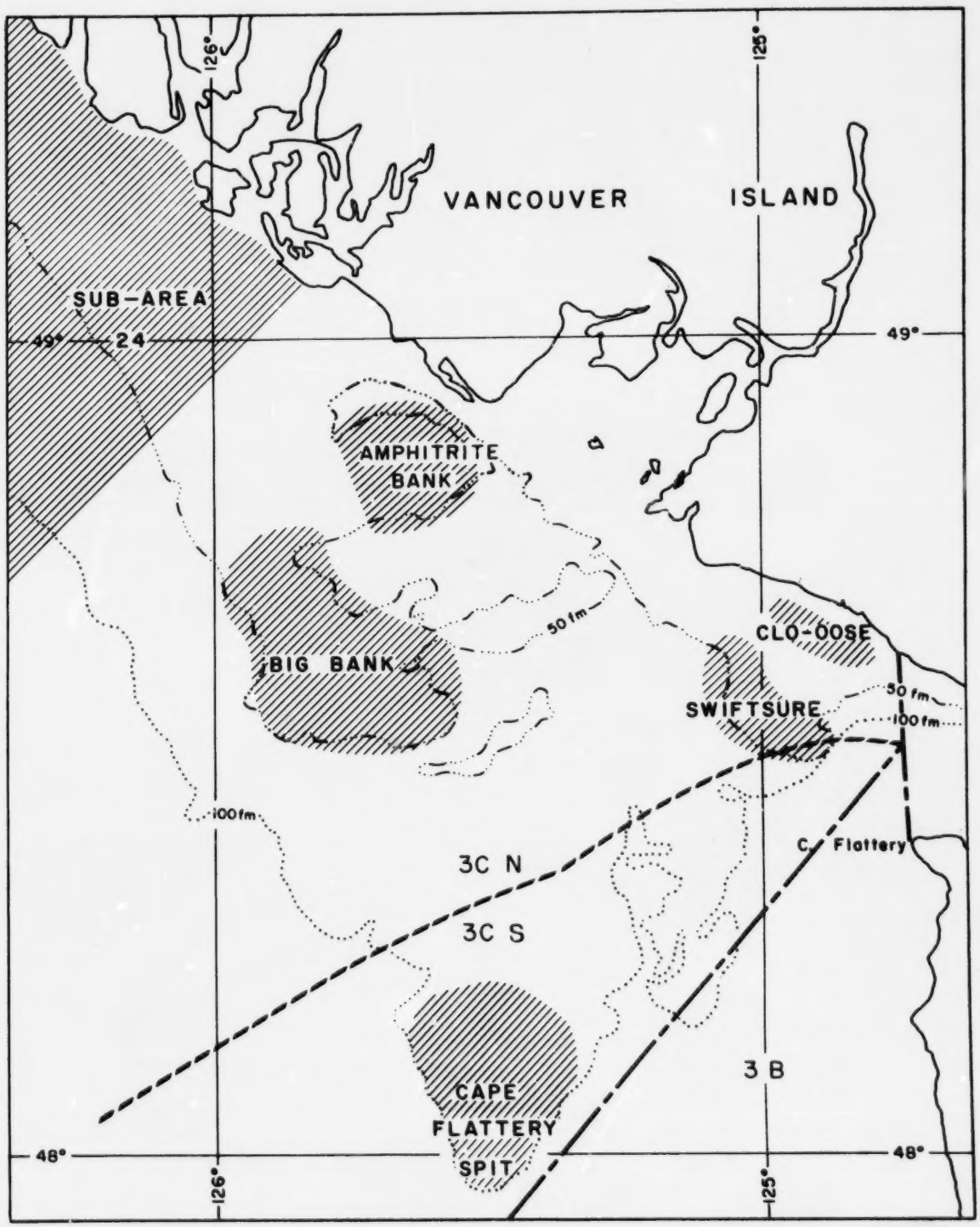

Fig. 3. Important trawling grounds in Area 3C-N.

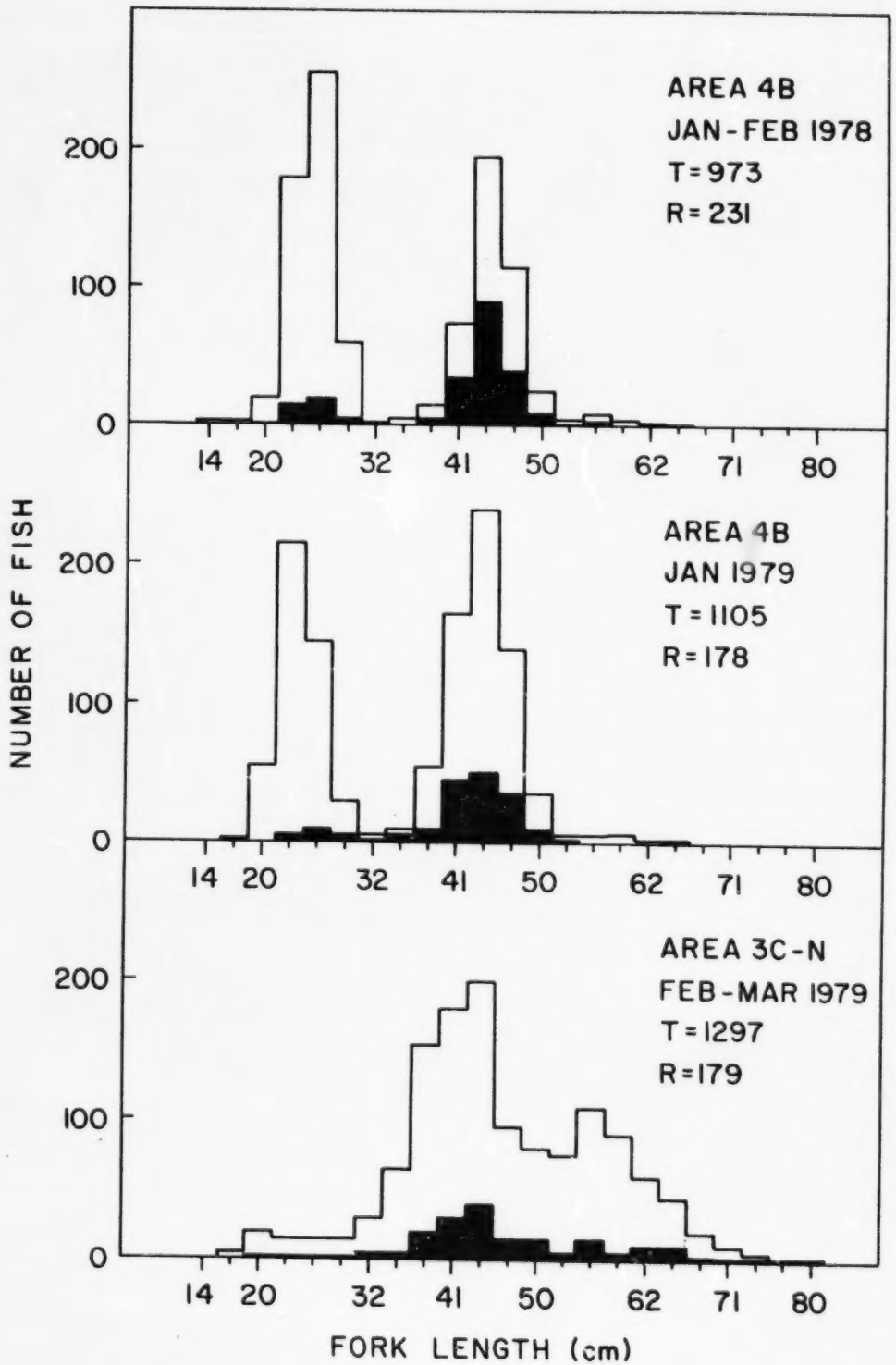

Fig. 4. Length-frequencies (nos.) of Pacific cod tagged and released (T), and recaptured (R: shaded area) from the 1978-79 experiments in Areas 4B and 3C-N. (Grouped in 3-cm intervals; 14 = 13-15, etc.)

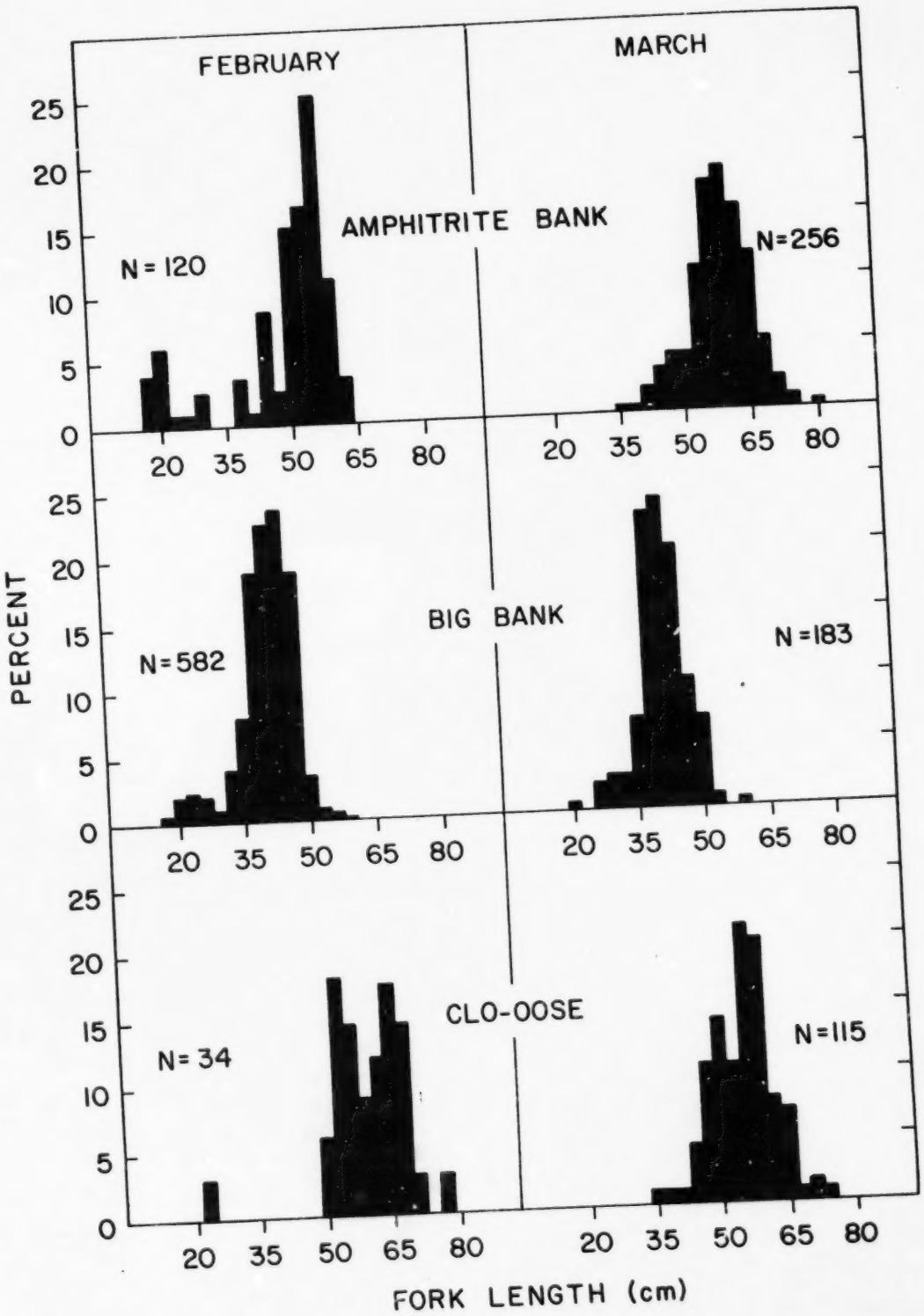

Fig. 5. Length frequencies (%) of Pacific cod tagged and released in Area 3C-N during February-March 1978-79, by month and ground. (Grouped in 3-cm intervals; 20 = 19-21 cm, etc.)

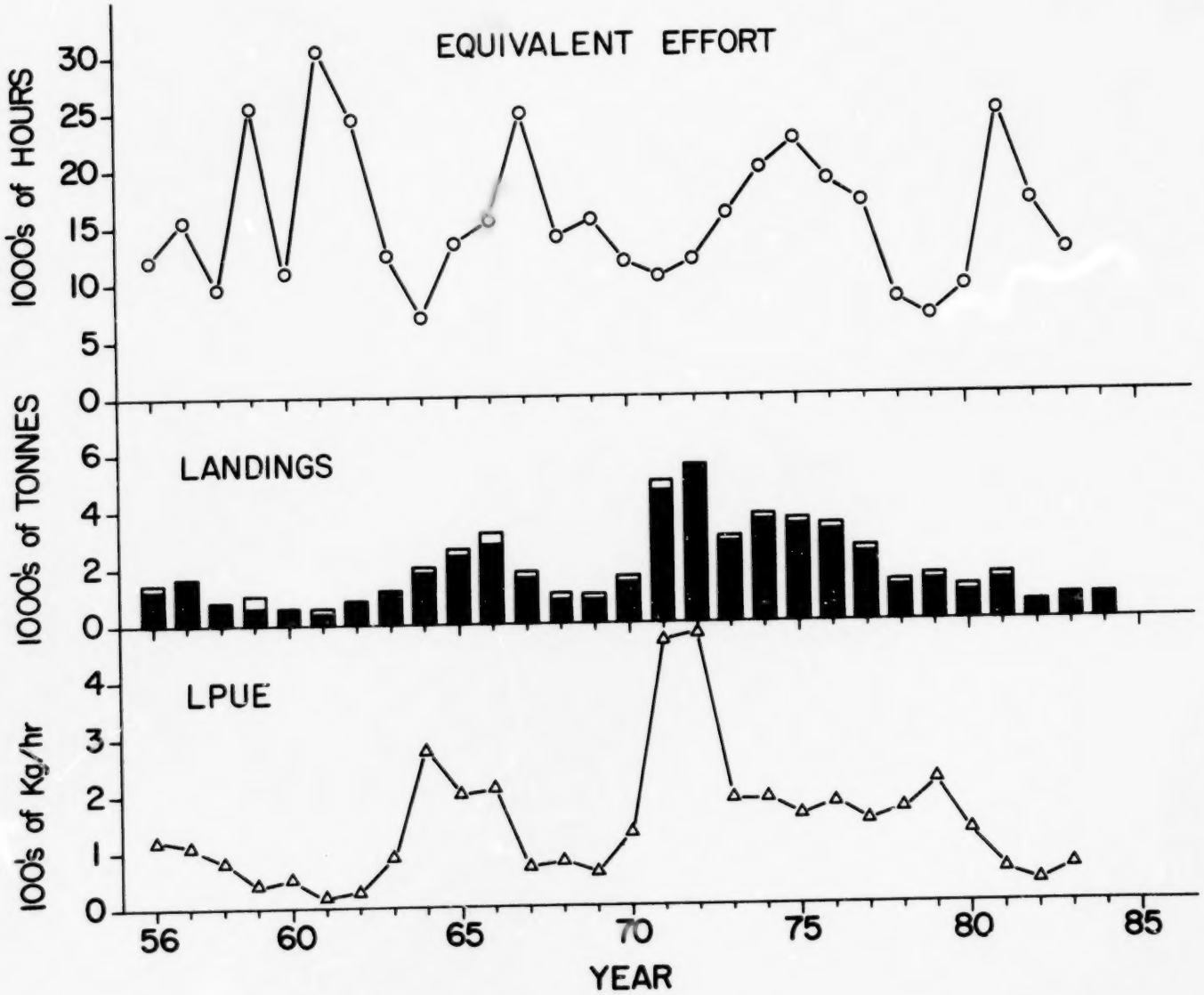

Fig. 6. Canada-U.S. landing statistics for Pacific cod off west Vancouver Island (Areas 3C + 3D), April-March 1956-84. (Shaded area = landings from Area 3C-N.)

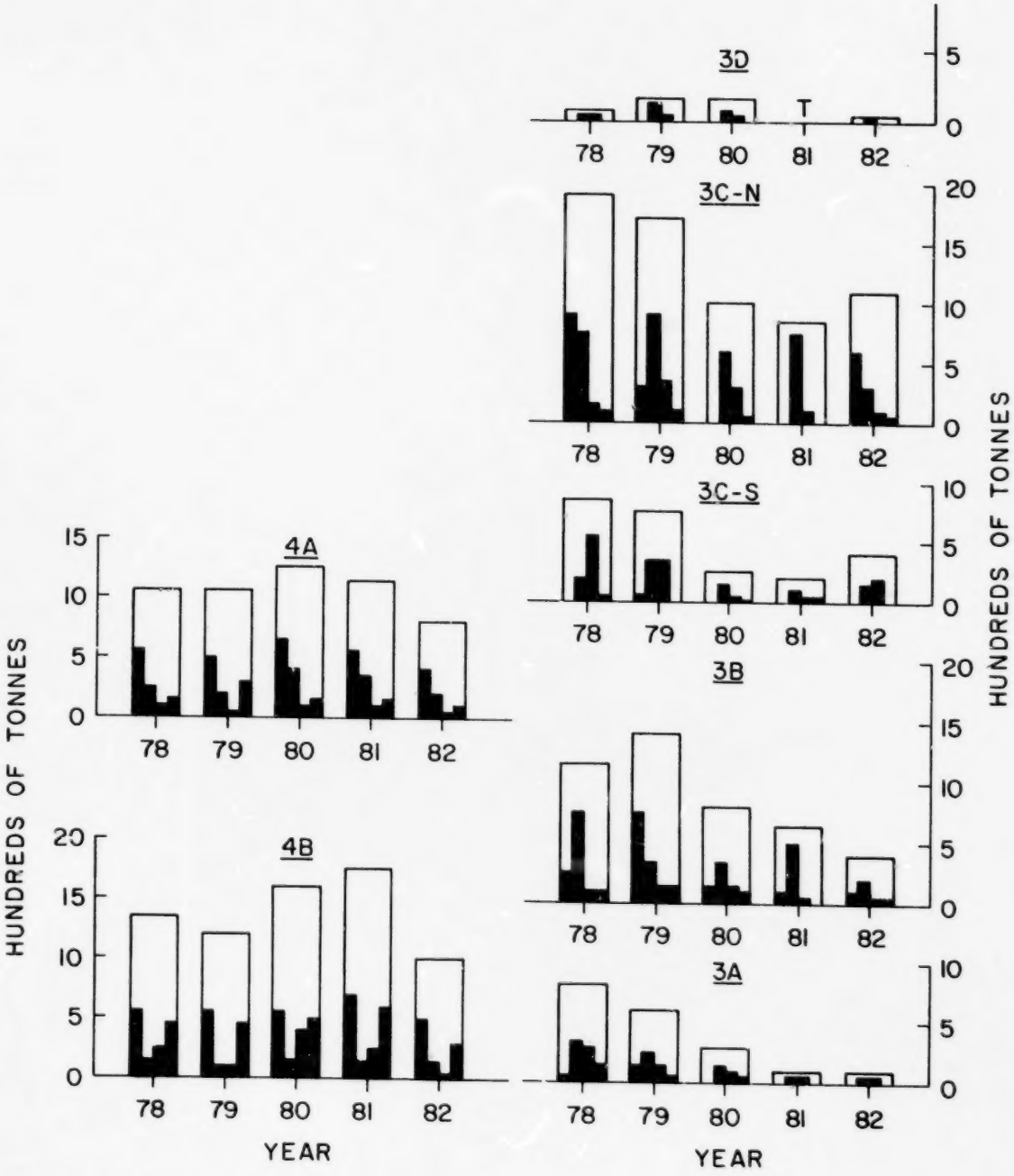

Fig. 7. Canada-U.S. landings (t) of Pacific cod from selected major statistical areas, by quarter-year, 1978-82.

Appendix table 1. Pre-release mortality rates (%) and recapture rates (%), by age-class, for Pacific cod tagged in the 1978 Swanson Channel experiment, and not held overnight. (Numbers in parentheses include cod held overnight.)

	Age (y)[a]			
	1	2	>2	Total
Total nos. tagged	457(618)	416(526)	10(17)	883(1,161)
Nos. died	81(110)	57 (90)	- (2)	138 (202)
%	17.7(17.8)	13.7(17.1)	- (11.8)	15.6 (17.4)
Versus age 2:				
χ^2	2.647(0.094)	-	-	-
P[b]	>.10(>.70)	-	-	-
Nos. released	376(508)	359(436)	10(15)	745 (959)
Nos. recaptured	29 (40)	154(183)	3 (6)	186 (229)
%	7.7(7.9)	42.9(42.0)	30.0(40.0)	25.0 (23.9)
Versus age 2:				
χ^2	121.6(151.2)	-	-	-
P[b]	<.01(<.01)	-	-	-

[a]Age 1 = <34 cm; age 2 = 34-54 cm; age >2 = >54 cm.
[b]P = probability of a larger χ^2 due to chance alone.

Appendix table 2. Pre-release mortality rates (%) and recapture rates (%), by age-class, for Pacific cod tagged in the 1979 Swanson Channel experiment.

	Age (y)[a]			
	1	2	>2	Total
Total nos. tagged	451	645	10	1,107[b]
Nos. died	90	43	-	133
%	20.0	6.7	-	12.0
Versus age 2:				
χ^2	44.0	-	-	-
p^c	<.01	-	-	-
Nos. released	361	602	10	974
Nos. recaptured	14	146	1	161
%	3.9	24.3	10.0	16.5
Versus age 2:				
χ^2	67.6	-	-	-
p^c	<.01	-	-	-

[a]Age 1 = < 34 cm; age 2 = 34-54 cm; age >2 = >54 cm.
[b]Includes one fish of unknown length.
[c]p = probability of a larger χ^2 due to chance alone.

Appendix table 3. Pre-release mortality rates (%) and recapture rates (%), by age-class, for Pacific cod tagged in Area 3C-N (all banks) during February-March 1979.

		Age (y)[a]			
		1	2	>2	Total
Total tagged		115	1,203	390	1,718
Nos. died		42	325	54	421
%		36.5	27.0	13.9	24.5
Versus age 2:					
	χ^2	4.721	-	-	-
	P[b]	<.05	-	-	-
Versus age >2:					
	χ^2	29.6	28.2	-	-
	P[b]	<.01	<.01	-	-
Nos. released		73	878	346	1,297
Nos. recaptured		6	133	41	180
%		8.2	15.2	11.9	13.9
Versus age 2:					
	χ^2	2.593	-	-	-
	P[b]	>.10	-	-	-
Versus age >2:					
	χ^2	0.798	2.214	-	-
	P[b]	>.30	>.10	-	-

[a]Age 1 = <31 cm; age 2 = 31-54 cm; age >2 = >54 cm.
[b]P = probability of a larger χ^2 due to chance alone.

Appendix table 4. Pre-release mortality rates (%) and recapture rates (%), by age-class for Pacific cod tagged on Amphitrite Bank during February-March 1979.

	Age (y)[a]			
	1	2	>2	Total
Total number tagged	25	142	284	451
Nos. died	8	22	38	68
%	32.0	15.5	13.4	15.1
Versus age 2:				
χ^2	3.930	-	-	-
P[b]	<.05	-	-	-
Versus age >2:				
χ^2	6.287	0.349	-	-
P[b]	<.02	>.50	-	-
Nos. released	17	120	246	383
Nos. recaptured	1	8	28	37
%	5.9	6.7	11.4	9.7
Versus age >2:				
χ^2	-	2.022	-	-
P[b]	-	>.10	-	-

[a]Age 1 = <31 cm; age 2 = 31-54 cm; age >2 = >54 cm.
[b]P = probability of a larger χ^2 due to chance alone.

Appendix table 5. Pre-release mortality rates (%) and recapture rates (%), by age-class, for Pacific cod tagged on Big Bank during February-March 1979.

	Age (y)[a]			
	1	2	>2	Total
Total nos. tagged	88	995	11	1,094
Nos. died	33	293	3	329
%	37.5	29.4	27.3	30.1
Versus age 2:				
χ^2	3.930	-	-	-
p[b]	<.05	-	-	-
Versus age >2:				
χ^2	6.287	0.349	-	-
p[b]	<.02	>.50	-	-
Nos. released	55	702	8	765
Nos. recaptured	5	117	2	124
%	9.1	16.7	25.0	16.2
Versus age 2:				
χ^2	2.165	-	-	-
p[b]	>.10	-	-	-

[a]Age 1 = <31 cm; age 2 = 31-54 cm; age >2 = >54 cm.
[b]p = probability of a larger χ^2 due to chance alone.

Appendix table 6. Pre-release mortality rates (%) and recapture rates (%), by age-class, for Pacific cod tagged on Clo-oose Ground during February-March 1979.

	Age (y)[a]			
	1	2	>2	Total
Total nos. tagged	2	66	105	173
Nos. died	1	10	13	24
%	50.0	15.2	12.4	13.9
Versus age >2:				
χ^2	-	0.267	-	-
p[b]	-	>.50	-	-
Nos. released	1	56	92	149
Nos. recaptured	-	8	11	19
%	-	14.3	12.0	12.8
Versus age >2:				
χ^2	-	0.169	-	-
p[b]	-	>.80	-	-

[a]Age 1 = <31 cm; age 2 = 31-54 cm; age >2 = >54 cm.
[b]p = probability of a larger χ^2 due to chance alone.

Appendix table 7. Distribution of individual Pacific cod, by location and time of tagging and recapture, tagged in Area 4B during January-February 1978-79.

Area 4B	Trincomali	MSA 18	Swanson	Satellite	Turbo	Prevost	MSA 19	Area 4A	MSA 80	Area 3C-N	Swiftsure
				Swanson Channel -- Jan-Feb 1978							
Jan 78	Feb 78 (2)	Jan 78 (3)	Jan 78 (2)	Jan 78 (10)	-	Mar 78 (4)	Jan 78	-	Mar 78 (2)	-	-
Feb 78		Feb 78	Feb 78 (55)	Feb 78 (2)			Sep 78		Apr 78		
Feb 79			Jan -	Mar 78					Jun 78		
			Feb 78 (27)	UNK (2)					Jul 78		
			Mar 78 (40)						Aug 78		
			Apr 78 (13)						Sep 78		
			May 78 (2)						Oct 78 (3)		
			Sep 78 (14)						Mar 79 (3)		
			Oct 78 (5)						Mar 80		
			Nov 78 (2)								
			Dec 78								
			Jan 79 (2)								
			Feb 79								
			Jul 79								
			UNK (2)								
				Swanson Channel -- January 1979							
Feb 79	-	Feb 79 (10)	Jan 79 (18)	Jan 79 (3)	Mar 79	-	Apr 79	-	Jul 79 (2)	May 79 (2)	-
			Feb 79 (9)	Feb 79 (7)					Aug 79		
			Mar 79 (3)	Mar 79 (3)					Oct 79		
			May 79	Jul 79					Nov 79		
			Jul 79 (4)	Jan 80 (2)					Aug 80		
			Aug 79 (2)	Mar 80 (2)					Dec 80		
			Sep 79 (2)								
			Oct 79								
			Nov 79								

Appendix table 7 (cont'd)

Area 4B	Trincomali	MSA 18	Swanson	Satellite	Turbo	Prevost	MSA 19	Area 4A	MSA 80	Area 3C-N	Swiftsure
				Trincomali Channel — January 1979							
Feb 79 (2) Apr 79 (3) Jul 79 Oct 79	May 79 (4)	-	Jan 79 Feb 79 Jun 79	Jun 79	-	-	-	-	-	May 79 (3)	May 79

Appendix table 8. Distribution of individual Pacific cod, by location and time of tagging and recapture, tagged in Area 3C-N during February and March 1979.

Area 3C-N	Amphitrite	Big Bank	Deep Big Bank	Pachena	Swiftsure	Recapture location: Area 3D	Area 3C-S	Area 3B	Areas 3A & 3B	Area 3A	Area 4B	MSA 20	MSA 19	MSA 14	Area 4A	MSA 86
Amphitrite Bank -- February																
May 79 Jun 79 May 80	Apr 80 May 80	May 79 Jul 79 Aug 80 (2)	-	-	May 79	-	Jul 79	-	Jun 79	-	-	-	-	-	-	Jan 80
Amphitrite Bank -- March																
May 79 (3) Jun 79 Jul 79 Oct 79	Jun 79 (2) Mar 82	Jul 79	-	-	May 79	Apr 79 May 79	-	-	Jun 79	-	-	Feb 80	Sep 79 Oct 79 Nov 79	-	-	-
Big Bank -- February																
May 79 (8) Jun 79 Jul 79 (7) Aug 79 (3) Sep 79 (3) May 80	May 79 (6) Oct 79 Apr 80 May 80	Apr 79 May 79 (4) Jun 79 (11) Jul 79 (9) Aug 79 (11) Oct 79 Apr 80 Oct 80	May 79	Jun 80	May 79 (4) May 80 Oct 80	-	-	-	-	Sep 80	Feb 80 Jul 80	-	Oct 79	Nov 79	Mar 79	Apr 80
Big Bank -- March																
May 79 (3) Jul 79 (2) Jul 80	Apr 80 May 80 (2)	May 79 (3) Jun 79 Jul 79 (4) Aug 79 Sep 80 Oct 80	-	-	Apr 79	-	-	May 79 Nov 79	-	-	-	-	-	-	-	Apr 80
Clo-oose -- February																
May 80	-	-	-	-	Apr 79	-	-	Sep 79	-	-	-	Aug 79	-	-	-	-
Clo-oose -- March																
May 79	-	May 79	-	-	Apr 79 (2) May 79 (4)	-	Jul 79	-	-	-	-	-	Sep 79 Nov 79 Nov 80	-	-	-